THE MANUFACTURE

OF

PULP AND PAPER

VOLUME IV

Pulp and Paper Manufacture

IN FIVE VOLUMES

An Official Work Prepared
under the direction of the

Joint Executive Committee of the Vocational Education Committees of the Pulp and Paper Industry of the United States and Canada

THE

MANUFACTURE

OF

PULP AND PAPER

A TEXTBOOK OF MODERN PULP
AND PAPER MILL PRACTICE

Prepared Under the Direction of the Joint Executive
Committee on Vocational Education Representing
the Pulp and Paper Industry of the
United States and Canada

VOLUME IV

PREPARATION OF RAGS AND OTHER FIBERS; TREATMENT OF WASTE PAPERS;
BEATING AND REFINING; LOADING AND ENGINE SIZING; COLORING;
PAPER-MAKING MACHINES

Authors: E. C Tucker, A.B.; Ed. T. A. Coughlin, B.S., Ch.E.; Arthur B.
Green, A.B., S.B.; Ross Campbell, B.S.; J. W. Brassington;
Judson A. DeCew, B.A.Sc.; C. J. West, Ph.D.; James
Beveridge; and others.

FIRST EDITION

PREFACE

In numerous communities where night schools and extension classes have been started or planned, or where men wished to study privately, there has been difficulty in finding suitable textbooks. No books were available in English, which brought together the fundamental subjects of mathematics and elementary science and the principles and practice of pulp and paper manufacture. Books that treated of the processes employed in this industry were too technical, too general, out of date, or so descriptive of European machinery and practice as to be unsuitable for use on this Continent. Furthermore, a textbook was required that would supply the need of the man who must study at home because he could not or would not attend classes.

Successful men are constantly studying; and it is only by studying that they continue to be successful. There are many men, from acid maker and reel-boy to superintendent and manager, who want to learn more about the industry that gives them a livelihood, and by study to fit themselves for promotion and increased earning power. Pulp and paper makers want to understand the work they are doing—the how and why of all the various processes. Most operations in this industry are, to some degree, technical, being essentially either mechanical or chemical. It is necessary, therefore, that the person who aspires to understand these processes should obtain a knowledge of the underlying laws of Nature through the study of the elementary sciences and mathematics, and be trained to reason clearly and logically.

After considerable study of the situation by the Committee on Education for the Technical Section of the Canadian Pulp and Paper Association and the Committee on Vocational Education for the Technical Association of the (U. S.) Pulp and Paper Industry, a joint meeting of these committees was held in Buffalo

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in September, 1918, and a Joint Executive Committee was appointed to proceed with plans for the preparation of the text, its publication, and the distribution of the books. The scope of the work was defined at this meeting, when it was decided to provide for preliminary instruction in fundamental Mathematics and Elementary Science, as well as in the manufacturing operations involved in modern pulp and paper mill practice.

The Joint Executive Committee then chose an Editor, Associate Editor, and Editorial Advisor, and directed the Editor to organize a staff of authors consisting of the best available men in their special lines, each to contribute a section dealing with his specialty. A general outline, with an estimated budget, was presented at the annual meetings in January and February, 1919, of the Canadian Pulp and Paper Association, the Technical Association of the Pulp and Paper Industry, and the American Paper and Pulp Association. It received the unanimous approval and hearty support of all; and the budget asked was raised by an appropriation of the Canadian Pulp and Paper Association and contributions from paper and pulp manufacturers and allied industries in the United States, through the efforts of the Technical Association of the Pulp and Paper Industry.

To prepare and publish such a work is a large undertaking; its successful accomplishment is unique, as evidenced by these volumes, in that it represents the cooperative effort of the Pulp and Paper Industry of a whole Continent.

The work is conveniently divided into sections, and bound into volumes for reference purposes; it is also available in pamphlet form for the benefit of students who wish to master one part at a time, and for convenience in the class room. This latter arrangement makes it very easy to select special courses of study; for instance, the man who is specially interested, say, in the manufacture of pulp or in the coloring of paper or in any other special feature of the industry, can select and study the special pamphlets bearing on those subjects and need not study others not relating particularly to the subject in which he is interested, unless he so desires. The scope of the work enables the man with but little education to study in the most efficient manner the preliminary subjects that are necessary to a thorough understanding of the principles involved in the manufacturing processes and operations; these subjects also afford an excellent review and reference textbook to others. The work

is thus especially adapted to the class room, to home study, and for use as a reference book.

It is expected that universities and other educational agencies will institute correspondence and class-room instruction in Pulp and Paper Technology and Practice with the aid of these volumes. The aim of the Committee is to bring an adequate opportunity for education in his vocation within the reach of every one in the industry. To have a vocational education means to be familiar with the past accomplishments of one's trade, and to be able to pass on a record of present experience for the benefit of those who will follow.

To obtain the best results, the text must be diligently studied; a few hours of earnest application each week will be well repaid through increased earning power and added interest in the daily work of the mill. To understand a process fully, as in making acid or sizing paper, is like having a light turned on when one has been working in the dark. As a help to the student, many practical examples for practice and study and review questions have been incorporated in the text; these should be conscientiously answered.

This volume deals with the manufacture of paper in the same authoritative and comprehensive manner as the subject of the manufacture of pulp was covered in the preceding volume. In spite of the antiquity of the paper industry, recent developements have been remarkable. There is still almost unlimited opportunity for exhaustive improvement in equipment and operation, and further advances will result from the study of what has already been accomplished. The progress that has been made in paper manufacture is expressed in the carefully prepared and exceptionally well illustrated text of this volume and the volume that follows. The importance of paper—its place as an absolute necessity in civilized life—is now fully recognized; and every one should be interested in and be able to understand the descriptions herein given of the processes and equipment involved in its manufacture. Never have such care and expense been devoted to the preparation of an industrial textbook.

A feature of this series of volumes is the wealth of illustrations, which are accompanied by detailed descriptions of typical apparatus. In order to bring out a basic principle, it has been necessary, in some cases, slightly to alter the maker's drawing,

and exact scales have not been adhered to. Since the textbook is in no sense a "machinery catalog," maker's names have been mentioned only when they form a necessary descriptive item. Much of the apparatus illustrated and many of the processes described are covered by patents, and warning is hereby given that patent infringements are costly and troublesome.

A valuable feature of this work, which distinguishes it from all others in this field, is that each Section was examined and criticised while in manuscript by several competent authorities; in fact, this textbook is really the work of more than one hundred men who are prominent in the pulp and paper industry. Without their generous assistance, often at personal sacrifice, the work could not have been accomplished. Even as it stands, there are, no doubt, features that still could be improved. The Committee, therefore, welcomes helpful criticisms and suggestions that will assist in making future editions of still greater service to all who are interested in the pulp and paper industry.

The Editor extends his sincere thanks to the Committee and others, who have been a constant support and a source of inspiration and encouragement; he desires especially to mention Mr. George Carruthers, Chairman, and Mr. R. S. Kellogg, Secretary, of the Joint Executive Committee; Mr. J. J. Clark, Associate Editor and Mr. T. J. Foster, Editorial Advisor.

The Committee and the Editor have been generously assisted on every hand; busy men have written and reviewed manuscript, and equipment firms have contributed drawings of great value and have freely given helpful service and advice. Among these kind and generous friends of the enterprise are: Mr. M. J. Argy, Mr. O. Bache-Wiig, Mr. James Beveridge, Mr. J. Brooks Beveridge, Mr. H. P. Carruth, Mr. Martin L. Griffin, Mr. H. R. Harrigan, Mr. Kenneth T. King, Mr. Maurice Neilson, Mr. Elis Olsson, Mr. J. S. Riddile, Mr. George K. Spence, Mr. Edwin Sutermeister, Mr. F. G. Wheeler, and Bird Machine Co., Canadian Ingersoll-Rand Co., Claflin Engineering Co., Dominion Engineering Works, E. I. Dupont de Nemours Co., General Electric Co., Harland Engineering Co., F. C. Huyck & Sons, Hydraulic Machinery Co., Improved Paper Machinery Co., E. D. Jones & Sons Co., A. D. Little, Inc., E. Lungwitz, National Aniline and Chemical Works, Paper Makers Chemical Co., Process Engineers, Pusey & Jones Co., Rice, Barton & Fales Machine and Iron Works, Ticonderoga Paper Co., Waterous

Engine Works Co., Westinghouse Electric & Manufacturing Co., and many others, particularly the authors of the various sections, who have devoted so much time and energy to the preparation of manuscript, often at personal sacrifice.

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J. Newell Stephenson,
Editor

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For the

Joint Executive Committee on Vocational Education,

George Carruthers, *Chairman*,   R. S. Kellogg, *Secretary*,

T. L. Crossley,   R. S. Hatch,   G. E. Williamson.

Representing the Technical Section of the Canadian Pulp and Paper Association.	Representing the Technical Association of the (U. S.) Pulp and Paper Industry.
T. L. Crossley, *Chairman*,	R. S. Hatch, *Chairman*,
George Carruthers,	R. S. Kellogg,
A. P. Costigane,	F. C. Clark,
C. Nelson Gain,	W. S. Lucey,
J. N. Stephenson.	Ernst Mahler,
	J. D. Rue,
	A. D. Wood.

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SECTION 1

PREPARATION OF RAG AND OTHER FIBERS

By E. C. Tucker, A. B.

RAGS AND RAG FIBERS

INTRODUCTION

1. A Brief History of the Use of Rags in Paper Making.—The earliest human records were made on stone; in some countries scratched or chiseled, in others written with chalk or colored ore. Other and more convenient substances used later in various places were, pieces of wood—as bamboo, bark, leaves—and prepared skins, as parchment and vellum. At a very early date, the Egyptians prepared a writing material from papyrus, a tall reed growing in the Nile, and called it also *papyrus*, whence our word **paper**. It was made by peeling off the layers of the stem, laying the long ones side by side until a strip of the desired width was obtained, then crossing them with short pieces. The sap served as an adhesive; and, after drying in the sun, the papyrus could be rubbed to a surface that could be written on with ink.

A shortage of papyrus in Asia Minor resulted in the invention of *parchment*, a specially dried calf or goat skin, filled by rubbing in chalk. Because of a similar famine in Rome, *boards*, covered with wax, were used; they were written on with a sharp instrument called a *stylus*. Several layers of wax were sometimes put on the same tablet.

2. The early Greeks wrote letters, notes, mortgages, etc. on broken pieces of pottery. The Chaldeans and Syrians wrote their records in soft clay bricks, which were then baked. Librarians must have used wheelbarrows!

The Chinese were the first real pulp and paper makers. They soaked pieces of bamboo in pits of lime water and separated the fibers by pounding. Rag and other fibers were also used, the process of making the paper being essentially the same as in use now in making hand-made papers.

3. At the dawn of the Christian era, paper making from rag fibers was a well-established art in China. From there the secrets of the process spread westward, and were carried to Europe by the invasions of the barbaric tribes. During the middle ages, the process was improved and developed, and by the end of the fourteenth century it was firmly established throughout southern Europe.

In England, the development was very slow, for it was not until three centuries later that the industry took firm hold there. As would be expected, the delay with which the industry was developed in England was further reflected in this country, and it was not until the last half of the eighteenth century that paper making became common here, although the first mill was established in 1690, and the industry developed without interruption.

4. Early Methods of Converting Rags into Paper.—The early phases of the development of paper making are interesting. The first process for converting the rags into paper was crude and primitive. The rags were washed, and were then steeped in closed vessels for several days. During this treatment, a fermentation process took place which brought the mass to a pasty consistency. This pulp was then diluted, transferred to the vat, and made into sheets on a hand mold. (See *Hand-made Papers*, Vol. V.) The first advance from this method came with the introduction of stamping rods, to beat the rags into pulp; and this was the process in use in practically all of the small mills previous to 1750. The rags were washed, and were then transferred to oak tubs or mortars, partly filled with water. Here the rags were beaten and pulped by stamping rods, which were encased with an iron shoe at one end. In most of the mills, these stamping rods were operated by power from a small stream—in a few cases they were operated by hand. By this method, using water power, from 100 to 125 pounds of rags would be reduced to pulp in 24 hours in a typical mill.

5. During the period from 1750 to 1800, the Hollander beater engine was developed and brought into general use. This was a small and early type of the beating engine so well known today. Its introduction brought the first decided change in manufacturing equipment. It improved quality, increased production, and made possible the later rapid growth of the industry.

6. Paper-Making Raw Materials.—Prior to 1860, rag fibers, cotton and linen (with small quantities of jute and hemp), formed the total source of paper-making raw materials. Rags were used in all grades of paper, from news and wrapping paper to writing paper. This condition made rags very scarce, in spite of large importations from Europe. In 1850, more than twenty million pounds of rags were imported by the United States, and still the mills were short of raw material. The newspapers and periodicals of those days were full of pleas from paper-mill proprietors, asking the people to save their rags for some particular paper mill. The difficulty in obtaining a sufficient supply of raw material was the determining factor in the industry. Expansion was almost impossible.

The discovery of the processes of making pulp from wood—the soda, sulphite, and groundwood processes—finally relieved this situation, and gave the industry the opportunity to grow.

7. At the present time, most of the rags go into the class of paper known as *fine writing*, and for this type of paper the fiber from cotton or linen cloth has no equal; large quantities of low-grade rags are used for roofing papers, while burlap, strings (jute) and hemp rope are used for strong wrapping papers (manilas). These fibers are prepared for use directly in the paper mill, as distinguished from wood fibers, which receive their first treatment in the pulp mill. For this reason, and because of the considerable similarity in processes and apparatus, the preparation of straw and esparto grass is also included in this Section. The treatment of waste papers is covered in another Section.

Note.—**Cotton**[1] (gossypium). The cotton fiber, which is the basis of most rag papers, consists of a single hair-like cell, which is flattened and twisted when fully ripe. This appearance is a characteristic of fully matured cotton; it is not shown by unripe fiber or by that which has been injured

[1] Data on the characteristics of paper-making fibers, given in these notes, are based on information derived from Chemistry of Pulp and Paper Making, by E. Sutermeister. See also Section 1, Vol. III.

during growth. The fibers form the covering of the cotton seed, and they are removed from the seed by ginning. The length of the cotton fiber varies from 2 to 5.6 cm., and the diameter varies from 0.0163 to 0.0215 mm. The cell walls of mature cotton are thin, and they often present a granulated appearance or highly characteristic cross markings. Müller has analyzed raw cotton, with the following results:

	Per Cent
Water	7.00
Cellulose	91.35
Fat	0.40
Aqueous extract (containing nitrogenous substances).	0.50
Ash	0.12
Cuticular substance (by difference)	0.63
Total	100.00

SOURCES OF SUPPLY

8. New Rags, or Table Cuttings.—The supply of new rags for paper making comes largely from textile or garment factories, where cuttings and scrap ends of cloth are collected as by-products. The total amount of cuttings available from this source of supply is estimated at 40,000 tons per year. The only other use for this material seems to be the re-spinning of white knitted goods, and this in quantity only when the price of raw cotton is high.

This waste material is usually sold to a broker or middleman, who takes the entire accumulation of the individual factory; and it may include everything, from the floor sweepings to the choicest clippings of white linen or cotton. The middleman usually repacks this material and then sells it to the paper mills that use the different grades.

9. Old Rags.—The source of supply of old rags is quite different. In the first place, it is much more flexible. Being a waste product, so common to every home, there is little likelihood of a shortage; for a rise in price will always bring out rags. We are all familiar with the grotesque figure that travels our streets and alleys buying "ra—gs" from the housewife. His capital consists of a dejected horse and a dilapidated wagon. Each night he sells his day's collection to another rag man who owns a small warehouse, and who buys these mixed rags and bales them in carload lots, for sale to the grader. The **grader** sorts

the rags for re-sale (sometimes directly and sometimes through a broker) to the paper mill, in the case of cottons, or to the shoddy mill, in the case of woolens. The following figures give a slight idea of what a thousand pounds of mixed rags contain.

<div align="center">PAPER-MAKING RAGS</div>

	Lb.
No. 1 whites	25
No. 2 whites	50
Whites and blues	225
Jute bagging	125
Roofing stock	250
	675

<div align="center">NON-PAPER-MAKING RAGS</div>

	Lb.
Soft woolens	20
Hard woolens	125
Mixed linseys (half wool and half cotton)	20
Wiping rags	60
Quilts and white batting	85
Rubbish	15
	325
Total	1000 lb.

10. Uses of Rags.—No. 1 whites, No. 2 whites, and whites and blues, (known also as either two's and blues or thirds and blues) are used for writing paper, and the specifications for each of these grades will be found in Arts. **13** and **14**. The jute bagging is used by the wrapping-paper mill, and the roofing rags are used for making roofing paper. This is the lowest grade of stock; it includes everything, so long as it is rag.

The woolen rags go to the shoddy mills; they bring by far the highest prices of any of the grades.

Wiping rags are used by machine shops, etc., and consist of large pieces of good, sound colored cloth.

Quilts and batting go to the mattress industry. The rubbish consists of such material as old straw hats, shoes, etc., which must be baled and carted to the dump.

11. Transporting and Handling Rags.—Rags are transported and handled in machine-pressed bales that weigh from 400 to 1000 pounds, depending on the size and type of press. The

hand baling press is still largely used; it is by far the most economical method of baling where only a small number of bales are made each day. With this type of press, two men will turn out from 10 to 15 bales a day.

Where the volume of baling to be done is large enough, the power press is of course more economical. There are several types of those presses on the market any one of which does excellent work. A bale weighing 600 to 800 pounds is large enough for convenient handling in the mill.

CLASSIFICATION OF RAGS

SPECIFICATIONS

12. General Specifications.—There are certain general rules which should apply to all grades. Rubber, for example, in any form is a distinct menace to the manufacture of good paper; and it should be generally understood that rubber is not to be included in any of the packings of rags that are to be used for the manufacture of writing paper.

All grades, new and old, must be free of rubber, leather, wool, silk, paper or muss, unless otherwise specified. It is recommended that where a description of any grade is not available, the material is to be sold on specified sample.

Other general specifications, which should cover all grades of rags, unless they are sold strictly on representative samples, are: they should be dry, and they should be free from paint, grease, and other foreign materials.

SPECIFICATIONS BY GRADES

13. Old Rags.—Old rags are divided into various grades, each of which has its own trade name and specifications, which are as follows for old rags:

Extra No. 1 white cottons consist of large, clean, white cottons, free from knits, ganzies, canvas, lace curtains, collars, cuffs, shirt bosoms, bed spreads, new cuttings and stringy or mussy rags.

No. 1 white cottons consist of clean white cottons, free from lace curtains, ganzies and canvas. Need not be so large as

Extra No. 1 white cottons. Must not contain stringy or mussy rags.

No. 2 whites consist of soiled white cottons, free from dump rags, street rags, scorched rags, paint, greasy rags, or oily rags. Also free from button strips and seams from higher grades of whites.

Mixed whites should contain at least 40% of No. 1 whites and not more than 60% of No. 2 whites. They must not contain any of the material prohibited in the grades of which they are composed.

Street whites should consist of soiled white cottons from street or dump collection. They are likely to contain some foreign material, resulting from the manner in which they are collected, but the rags must be dry.

Twos and blues should be rags of strictly house collection, and should consist of No. 2 white cottons and light blue checks and prints. They should not contain the seams or buttons taken from higher grades of whites, nor should they contain dark blues of any description. They should not contain old corsets, small pieces of new rags, or rags smeared with paint, oil, or grease, nor should they contain any scorched rags.

Thirds and blues should be rags of strictly house collection, and may contain light pinks, greens, and blues, but should be free from dark reds, yellows and blacks, from quilts and feather ticks, canvas, tents and awnings, seams and strippings from higher grade rags, from rags smeared with paint, oil, or grease, and from small pieces of new rags or fine cut mussy rags.

Miscellaneous blues should be rags of all colors, free from solid black or satinet. Street or dump rags must not be present in excess of 25%.

Old blue overalls are to contain clean, blue overalls only, free from oil, grease or paint, and are understood to be free from miners' garments.

Black cotton stockings are to consist entirely of black cotton stockings, but white feet or edgings are permitted.

White cotton batting should contain only clean white cotton from quilts, mattresses and comforters; must be stripped of all rags.

White cotton-filled quilts should be quilts filled with white cotton batting only.

No. 1 white old lace curtains are to contain only clean, white lace curtains, free from starchy, knitted or crocheted material.

Besides these grades there are special classifications, such as underwear, flannelettes, hosiery, tarpaulins, filter press canvas, strings, rope, burlap, roofing stock, etc.

14. New Rags.—For new rags, the names of the grades and their specifications are:

No. 1 white shirt cuttings, heavy, are to consist of white cuttings such as accumulate from shirt factories and similar sources; must be strictly table cuttings and are to be free of starchy or loaded material. B.V.D. cuttings (dimity) may be included.

No. 1 white shirt cuttings, lawns, may contain materials of lighter weight than heavy shirt cuttings; they must be table cuttings and free of starchy or loaded material.

No. 2 white shirt cuttings are to consist of white shirt cuttings and lawns, consisting of house to house and shop collections, and not of table cuttings; may contain a small percentage of black threads, muss and soiled material; are to be free from oily rags.

No. 1 bleached strips, white or gray, are to consist of strips of white or gray cotton cuttings, coming from bleacheries; must be clean.

No. 1 soft unbleached cotton are to consist only of unbleached cuttings of a character similar to white shirt cuttings, heavy. Must be free of starchy or loaded rags, Canton flannels, shivy rags and drills.

No. 1 bleached shoe cuttings should be table cuttings of a nature used in lining shoes; are to be free of pasted stock.

No. 2 bleached shoe cuttings are the same as No. 1, but may contain pasted stock.

No. 1 unbleached shoe cuttings are to be the same as No. 1 bleached shoe cuttings, with the exception that they are to consist of unbleached cuttings and are to be free of pasted stock.

No. 2 unbleached shoe cuttings are the same as No. 1, but may contain pasted stock.

No. 1 fancy shirt cuttings are to be such table cuttings as accumulate from shirt factories and similar sources, consisting of white background with colored stripes.

No. 2 fancy shirt cuttings are to be composed of the same material as No. 1 fancy shirt cuttings, with the exception that

they need not be table cuttings; but must consist of material coming from house to house and shop collections; may contain black threads and soiled pieces.

Blue overall cuttings are to be such table cuttings as accumulate from overall factories and similar sources. This grade should be accompanied by sample showing whether the weave consists of a black-thread or white-thread back.

Washables or wrapper cuttings must be table cuttings; may contain material of lighter weight than fancy shirts, such as calicoes, ginghams, etc.; may contain solid colors, but are to be free of reds and blacks.

New light seconds are to consist of sheer, flimsy rags, light colored; solid colors are to be admitted or white backs with colored stripes. Need not be free from black threads.

Soiled bleachery rags are to consist of cuttings and remnants coming from bleacheries; may be soiled, but must be free from oil and grease.

No. 1 dark prints are to consist of all dark colors and unbleachable new material.

Cottonades are to consist of coarse, striped cotton-garment cuttings that look like wool but are free from wool. Brown cuttings and striped overalls may be included.

Besides the classes given, there are other grades and subdivisions. An interesting article on Rags, by Howard Atterbury, appeared in the *Pulp and Paper Magazine,* 1919, p. 1103.

TREATMENT OF RAGS BEFORE COOKING

PRELIMINARY THRASHING

15. The Rag Thrasher.—The first step in the actual preparation of rags for paper making is the preliminary thrashing.

The bales are opened up and the rags put through a rag thrasher, though some mills pass new rags directly to the sorters. The purpose of this machine is to open the rags up thoroughly, and to remove the loose dirt and dust that may be present.

The rag thrasher consists of a revolving cylindrical drum A, Fig. 1, about 40 inches in diameter, from which protrude hooks or pins B for thrashing the rags. The cylinder is enclosed, and there is a hopper C and gate D on one side for feeding in the rags,

and a gate E on the other side, for discharge after the rags are thrashed. Under the cylinder is a coarse screen F, which allows the dirt to drop through, but which holds the rags in contact with the drum. At the top, a stick of timber G, about 12 inches from the drum, serves as a whip as the rags beat against it. Fine dust held in suspension is removed by a suction fan through the pipe H. The dirt is shoveled out from below the screen.

Fig. 1.

In operation the hopper is filled, then the gate is opened, and the rags are allowed to slide into the thrasher. After 4 or 5 minutes' thrashing the rags are discharged by raising the gate on the other side. They are then ready for the sorters.
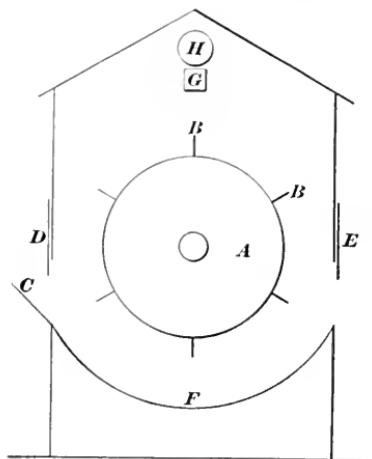
16. Thrasher Dust and Loss in Weight.—Loss in weight due to the amount of dust and dirt taken out by the thrashers depends largely, of course, on the character of the rags going in. In the case of new table cuttings, the loss is very small; while in the case of street whites, it may run as high as 8 % to 10 % or higher.

SORTING AND INSPECTING

17. Sorting Rags.—From the thrasher, the rags usually are loaded into baskets and turned over to women, who *strip* and *sort* them. These sorters work at tables, Fig. 2, which are really shallow boxes with a coarse screen bottom. Large scythe-like knives are used for stripping buttons, ripping seams, cutting large rags, etc. In the case of new rags, there is usually very little stripping to do. The sorters in this case look particularly for foreign material, such as metal, rubber, leather, etc., that must be taken out, and also for the occasional pieces of silk or wool or paper that may be there. Pockets are always searched; the findings include knives, rings, money and trash.

In the case of old rags, the sorter's work is more difficult. These old rags consist mainly of cast-off cotton garments.
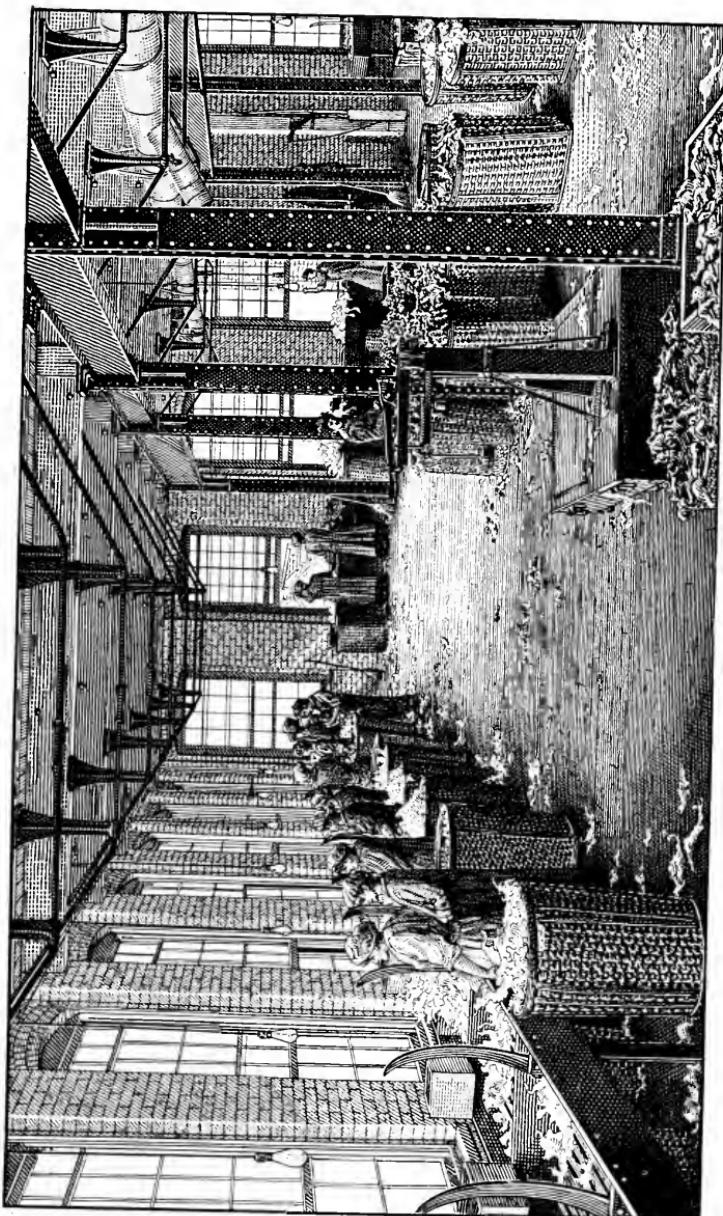
Fig. 2.

These garments must first be stripped on the knife; that is, the buttons are stripped off, the pockets and heavy seams ripped up, and all metal is taken off. When this is finished, the rags are graded as to color, where this is necessary, separate baskets receiving the different grades and colors; for instance, yellows and reds, known as "hard" colors, as they are hard to bleach, are saved for dark-colored paper. The strippings and discarded stock make what the paper maker knows as **muss,** and this material goes into the manufacture of roofing paper. Good woolens go to the shoddy industry.

18. Why Rubber and Metal Are Avoided.—Perhaps the reader is wondering why the paper maker speaks so often of rubber and metal, and is so anxious to avoid them. It is due to the desire on his part to make clean paper. Hold a sheet of writing paper up to the light and look for the dirt. Now rubber and metal are not affected by the cooking, the washing, or the bleaching. Once in, they go straight through the process, only getting cut up into small pieces and finally spreading through the whole web of paper. "But," one may ask, "How is it that you sometimes find such things as rubber in new cuttings of cotton cloth?" It is there because of the large amount of rubber used in making cotton garments. There are rubber waist bands, sleeve bands, dress shields or goods waterproofed or pasted together with rubber. Such things as these, carelessly allowed to go in with good material, cause losses of thousands of dollars annually to the paper industry. Constant alertness is the only safeguard against troubles of this sort.

19. Inspection of Rags.—Rags coming from the sorters are usually sent to the inspectors or "over-lookers." These women go over the rags again very carefully, to make certain that all of the objectionable material is removed from the rags before it is passed on to the next process. The rag sorters must do conscientious work, if the mill is to make clean paper. Workers in the rag room are usually paid a certain amount per pound for rags sorted. This weighing is also a check on the quality of rags and quantity used.

20. Equipment of Rag-Sorting Room.—The equipment of the rag-sorting room is not elaborate. The rags are handled in large baskets, which are provided with casters, for ease of moving from place to place. The sorters work on tables provided with

half-inch-mesh wire screens on the working surface, this allows dirt, loose buttons, etc., to drop through into a box. Each of the sorters has, in addition, the stripping knife, set up in a convenient place on the table or screen at which she works; this is a source of accidents, usually of a minor nature, but likely to cause infection; even a scratch should be given first-aid treatment.

Particular attention must always be given to the ventilation of the rag room, and a special ventilating system should be provided to remove the dust and lint that always comes from handling the rags. A fan usually draws the dusty air in a gentle stream from just below the screen and delivers it to a large chamber, where the air practically comes to rest, and the dirt settles out.

CUTTING AND DUSTING

21. Reason for Cutting.—As the rags come from the sorters and inspectors, they are in fairly large pieces. In order to prevent them from roping, to produce uniform *half-stuff* (washed rags), and to facilitate handling all along the line, the rags are cut into pieces averaging in area from 10 to 20 square inches. For many years this work was done by women; now, however, the rag-cutting machine is practically always used, except in the case of linen rags, where the hand-cutting of rags is still quite general.

22. Rag Cutters.—The essentials of this cutter, Fig. 3, are a revolving knife cutting against a bed knife (like a lawn mower), and the means of feeding the rags to this knife. In many of the mills, two cutters in tandem are used. Tandem cutters are set at right angles so as to cut the rags in both directions.

23. One of the most recent machines on the market is the rag cutter, shown in Fig. 3. This machine uses slitters before the knife, and its operation is as follows: The rags are placed in the feed apron U at the top, and from there they fall in between the corrugated knives, or *slitters* X, which constantly rotate and slit the rags into strips lengthwise. The rags are stripped off these slitters by another set of corrugated rolls, and *clearers*, and fall into the intermediate, or slat, apron. This carries the strips along and feeds them endwise to the fly knife A, which

turns against a stationary bed knife and chops off the strips into rectangular blocks. The cut rags then fall to the delivery apron W, which carries them to the duster. All gears should be enclosed and care taken to keep hands from the knives. The bed knife is lowered or lifted by means of hand wheels H and screws, so as to regulate the distance from edge of bed knife to fly knife A.
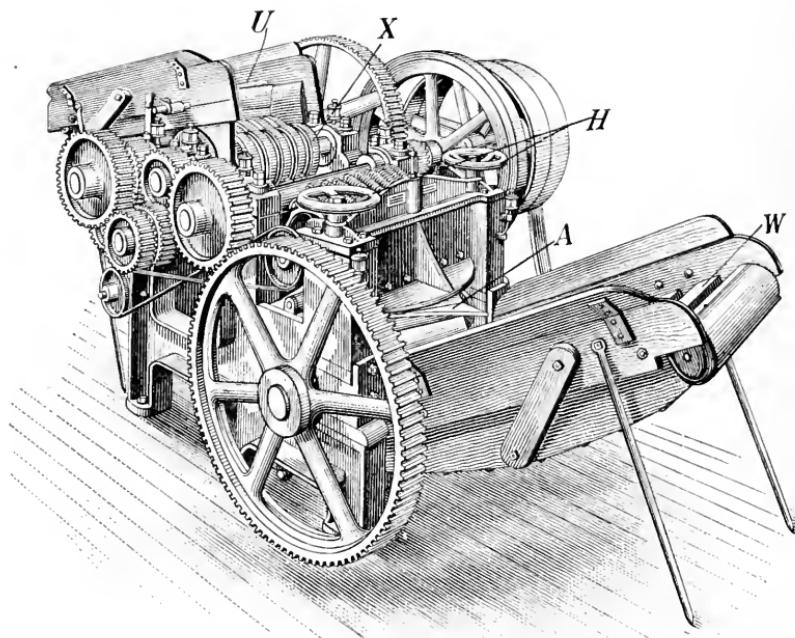
Fig. 3.

24. Dusters.—Rags, coming from the rag cutter, carry with them the dust produced by the cutting operation. This dust is too short-fibered to be of use, and would be lost in the later processes; it also carries with it a very considerable amount of dirt, which has to be taken out, if clean paper is to be made. For this purpose, different types of dusters are in use. Very often the rags are discharged from the rag cutter to a **railroad duster**. In this type of duster, revolving drums A, Fig. 4, with pins or teeth arranged helically around the drum, carry the rags over fine screens C. This type of duster is very simple. The rags are fed in at D; after passing the screen, they are deflected to

the next drum by the shape of the hood at E. This duster is rather harsh in its treatment of the rags, and the fiber loss is considerable. On the other hand, the harsh treatment eliminates a large amount of dirt, so that its use is common on old rags. The dirt collects in the box below the screen. The rags usually fall from the outlet F upon an apron conveyor.
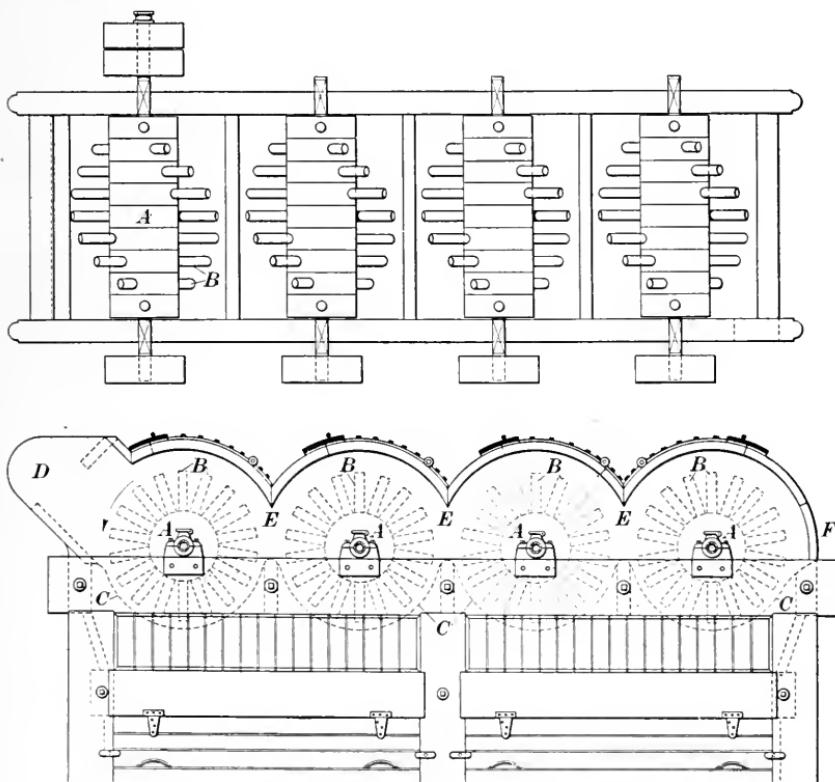
Fig. 4.

Another type often used is the **fan, or wing, duster**, Fig. 5. Here the rags are blown through the duster by a revolving drum A, with wings B arranged helically. At the same time, the outside screen C revolves in the opposite direction. D is the dust outlet. This makes an excellent duster, and is a type very generally used. Here the treatment is not so severe, and the fiber loss is less.

The cut rags are handled from the rag cutter to the boiler on aprons or in chutes; hence, the cutting, dusting and loading of the boiler really take place as one operation.   Often, however, it is necessary to prepare and pile the rags in advance.
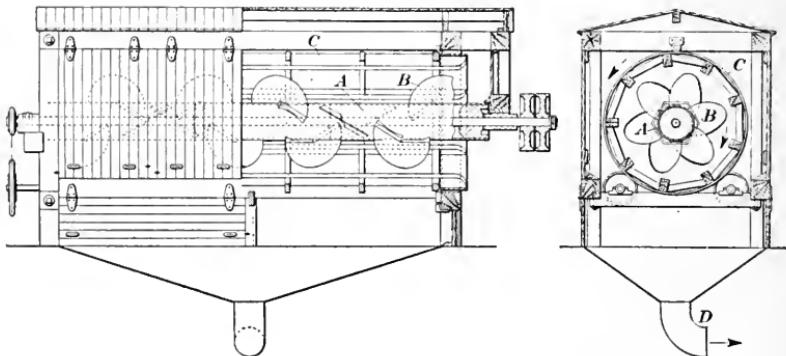
Fig. 5.

25. The Magnetic Roll.—In spite of all the care used in sorting and inspecting the rags, if metal is present, a certain amount of it always gets by.   The magnetic separating roll, Fig. 6, has been applied, within the last few years, for removing as much as
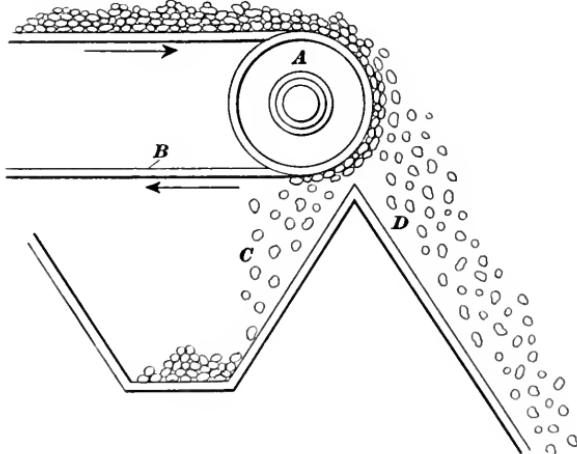
Fig. 6.

is possible of this material.   The magnetic pulley A is placed as the driving roll on one of the aprons B carrying the cut rags. Rags C containing iron or steel cling to the pulley, and are thus separated from the other rags D.

The following extract from a letter written by a manufacturer, in whose mill a magnetic separating pulley has been installed, gives some idea of what this pulley can accomplish:

"Tests show that we are taking out approximately 500 pieces of metal from each 10,000 lb., of old rags, run through. This material consists of hooks and eyes, metal clasps, tacks and nails, metal buttons, pins, needles, pieces of wire, etc., which are not detected by the women inspecting the rags. We estimate from several tests that this is about 75 % of the material which it would be possible to take out in this way.

Our separator roll is 12 inches in diameter, and is run at 76.8 r.p.m. This gives us an apron speed of 241 feet per minute."

QUESTIONS

(1) Name some of the materials first used for keeping records.

(2) As regards source of supply and character, how do new rags differ from old rags?

(3) (a) Of what do the sortings from paper-making rags consist? (b) what uses are made of them?

(4) How much loss is suffered in thrashing?

(5) (a) Mention some sources of rubber and iron in rags; (b) what effect have they on paper?

(6) Explain one type of duster and what it does.

COOKING OF RAGS

COOKING AND COOKING LIQUOR

26. Purpose of Cooking.—It may now be asked why the paper maker cooks the rags before making them into paper? In other words, what does this cooking process accomplish? We know that wood is cooked to get rid of the impurities (particularly lignin), and a pure cellulose is left. Now linen and cotton fibers are the nearest thing to be had in nature that corresponds to pure cellulose; but the rags used in paper making contain many undesirable impurities, which should be removed. First of all, the cooking softens and mellows the rag by removing the natural waxes and resinous material in the fiber. In addition, it removes the dirt and grease and loosens up the starch and loading material. It also starts the color in rags that have been dyed, and thus renders them readily bleachable. In some mills, it is the practice to take certain new white cuttings directly to the washing

engine, leaving out the cooking process. The writer does not consider this to be the best practice, although it is feasible in the case of new white cuttings. These rags are harsh, and they do not respond nearly as well to treatment as in the case where the same rags are mellowed by the cooking process. Uncooked rags are usually rather difficult to size properly; because, where the natural waxes have not been cooked out, the capillary attraction of the central canals is very hard to overcome with rosin size. Several high-grade mills have thoroughly tried out this practice, and they now insist that all rags shall be cooked.

Note.—Most of the fibrous raw materials that are treated in the paper mill are relatively pure cellulose, which is practically unaffected by the relatively mild alkaline cooking liquors and the weak oxidizing action of bleach solutions, in properly conducted mill operations. Cotton, linen, hemp and jute have already passed through operations, incidental to the textile and cordage industries, which have largely removed the non-cellulose matter originally associated with the fiber. With esparto, straw, bagasse, etc., the treatment is necessarily more severe than with textile wastes; but here too, the recovered cellulose has come through unaffected, because of its wonderful resistance to most chemical agents. Some of the more important reactions of cellulose have been mentioned in the Section on *Chemistry*, Vol. II, and the Section on the *Properties of Wood*, Part 2, Vol. III.

27. Cooking Liquor.—There are three different cooking liquors in general use in cooking rags: the liquor made with caustic lime; that made with caustic soda; and that made by using a combination of caustic lime and soda ash. Much has been written and said as to the advantages of any one of these processes over each of the other two, widely divergent opinions have been expressed, and two investigators reach diametrically opposite conclusions. Such being the case, no attempt will here be made to settle this argument. It is reasonably certain, moreover, that with careful handling, rag pulp (half-stuff) that is of excellent quality can be produced with any one of these cooking liquors. A few of the points usually brought up in a discussion of this subject may be of interest, however.

28. Lime or calcium hydrate attacks the natural waxes energetically, and at a temperature of 120°C. (248°F.) they are saponified in less than two hours. Lime also attacks, but less readily, the oils or grease that may be present in the rags. The one big drawback is that it forms calcium salts, most of which are not soluble, and, being rather sticky, they adhere to the fiber.

This makes the washing much more difficult, since the small particles of lime soap must be carried away mechanically in the wash water. It is to be noted, however, that this is not an insurmountable obstacle, and that rags cooked with lime are being washed satisfactorily all over the country every day. In addition, it is to be remembered that lime is especially adapted to the decomposition of a large number of dyestuffs used in coloring cloth; being a weak alkali, it has no action on cellulose. Consequently, it is used very widely because of the excellent color obtainable with it. Paper makers have long claimed that when lime is used in the cooking, the resulting product does not have nearly as much tendency to turn yellow as is the case when caustic soda or soda ash is used.

29. Caustic soda is of course a more active agent than lime. It readily attacks the natural waxes and the oils or grease that may be present in the rags. It removes glues and starch sizings thoroughly, and it forms products that are soluble in water and which are easily washed out. In strong solutions and at high temperature, the cellulose itself may be acted on. The writer's experience has been, however, that it does not attack the colors as thoroughly as does lime.

30. The liquor made with a combination of lime and soda ash is, of course, a mixture of the other two, with a certain amount of calcium carbonate in suspension. The soda present increases its causticizing action, and it more effectually removes the albuminous substances that may be present. As with the lime alone, however, the resulting products are all insoluble, since any sodium salt formed will immediately be precipitated by the lime, to form the calcium salt and caustic soda. Rags of dark color and very dirty rags are best cooked in the caustic soda or lime-soda ash liquor. When lime CaO and soda ash Na_2CO_3 are mixed in solution, the lime first forms the hydrate $Ca(OH)_2$, then the following reaction occurs:

$$Ca(OH)_2 + Na_2CO_3 = CaCO_3 + 2NaOH$$
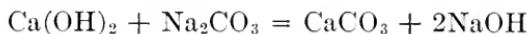
The $CaCO_3$, calcium carbonate, settles out, leaving a solution of caustic soda NaOH.

31. The tank in which the liquor is prepared is usually so situated that the liquor can be transferred to the boiler by gravity, through pipes; it usually holds the quantity required for one cook or one "bleach." If lime is used, the tank should contain an

agitator, similar to that in a vertical stuff chest (See Section on *Beating and Refining*); and the resulting liquor should be screened before going to the boiler or to storage, in order to make sure that all lumps are removed. When lime and soda ash are used, the latter should first be dissolved, then the necessary lime should be added and well stirred. Let settle, and draw off through a strainer.

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BOILERS

32. Types of Boilers.—The cut and dusted rags are usually fed into the boiler by a chute, which feeds into the manhole at the top. In the rotary boiler, which is the one in general use, the rags must be packed into the boiler by a man inside. This

FIG. 7.
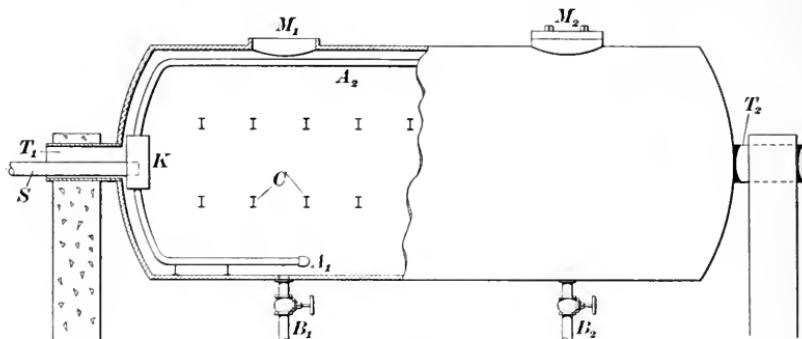
man tramps down the rags and stows them into the sections of the boiler not reached by the chute. He should wear a respirator to keep dust from his lungs. When the boiler is partly filled, the cooking liquor is started in, for when the rags are wet they pack much more closely. It is essential that the boiler be packed evenly and well to obtain uniform cooking. The liquor pipe is introduced through the manhole at which the man is not working. An open vertical pipe, stuck into the boiler, assists in finding the liquor level.

33. The boiler in general use in this country is the cylindrical rotary shown in part section in Fig. 7. This is a large cylindrical drum (usually about 8 feet in diameter by 24 feet in length) of such dimensions that it will hold about 5 tons of rags. In practice, the cooking liquor, made up with water if necessary, is brought up to the level of the journals T_1 and T_2 and, in some

cases, even filling the boiler two-thirds full; more water forms as the cooking steam condenses. During the cooking process, this boiler turns at the rate of about one revolution per minute. Note that the steam is admitted directly through pipe S in the trunnion T_1, and is distributed by the different lengths of pipe, A_1, A_2, usually three, opening at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ the length of the boiler. In order to avoid the possibility of burning the rags, nearly all of these boilers are equipped with the Kinne valve. This is a sleeve-type valve, situated in the journal at K, and so set that steam can enter the distributing pipe only when the pipe is in a
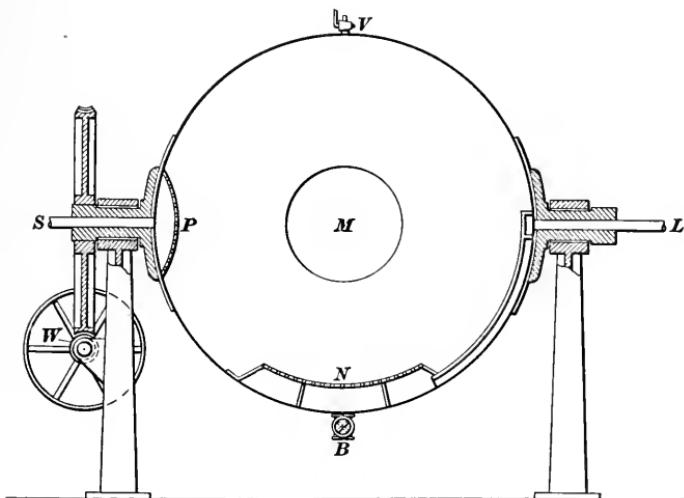
Fig. 8.

position below the cooking liquor, as at A_1. However, in many rag boilers, steam is introduced directly at the trunnion through a perforated plate. B_1 and B_2 are blow-off pipes, the inlets of which are covered by screen S; C indicates V-shaped spikes, to keep rags from being rolled into ropes; M_1 and M_2 are manholes. At the end of the cook, the liquor is drained or blown off through B_1 and B_2; it is not profitable to recover the chemicals in it.

When the cooking operation is finished, the steam is turned off and the boiler is stopped, with the valves B_1 and B_2 at the bottom in position to connect with the blow-off pipes; this connection is made, and the valve is opened. The steam pressure blows off the boiling liquor, which carries with it large amounts of insoluble material in suspension. When the cook is thoroughly

blown, the manholes are opened, and the boiler is rotated as long as rags fall out readily; then it is brought to a position such that the rags may be pulled out by the workmen (using long-handled 2-prong hooks) into cars or onto the floor, to drain.

34. A boiler of the same general type, largely used in England and Europe, and somewhat on this continent, is the revolving spherical boiler shown in Fig. 8. This boiler is set on trunnions, and is operated on the same principle as the cylindrical rotary; it finds some favor in cooking straw. Its only advantage is that higher steam pressures can be carried in it; it also empties a little faster than the cylindrical form of boiler, but has less capacity.
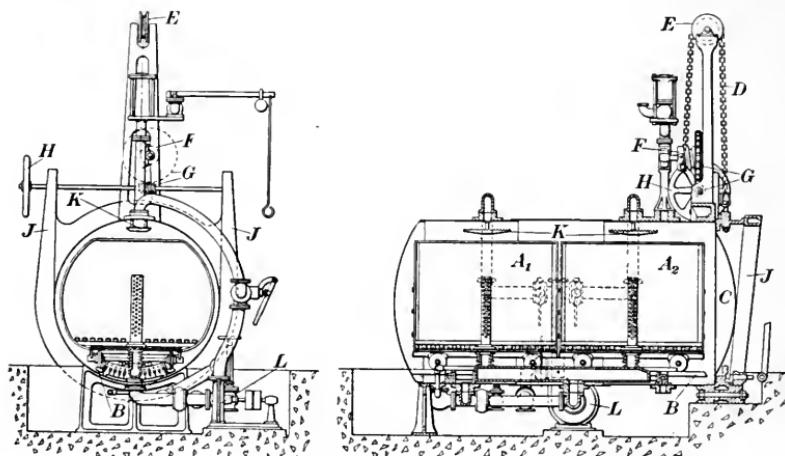
Fig. 9.

The boiler is turned by means of the worm gear and pulley mechanism W. Steam enters at S, and is distributed by the perforated plate P; lye enters at L, or through the manhole; V is an air vent; B is a blow-off valve; N is a perforated plate; and M is a manhole, for charging and emptying.

35. Another cooker that may be of interest is the **Mather kier**, Fig. 9, which is an adoption into paper making from the textile industry. It has been applied to the cooking of rags for paper making in England, and the results reported seem to merit attention. The results obtained are given in a report by Cross and Bevan. "Its dimensions are 8 feet long by 7 feet in diameter, and it is adapted to hold two wagons A_1, A_2, of special design, which are run into the kier on tracks B. In order, however, to economize

time, six wagons are employed, four being either filled or washed, while the other two contain rags in process of treatment in the kier. The cut and dusted rags are delivered automatically from a chute, directly into the wagons. The running of the wagons into the kier and the closing of the door C occupy only some 2 or 3 minutes. The door is lifted by means of chain D passing over pulley E to chain drum F; the latter is attached to worm and worm wheel G, which is operated by hand wheel H. The door slides between frames J, which are wedge shaped; thus the farther the door slides down, the tighter the joint between it and the body of cooker. As soon as door C is closed, the rags are saturated with caustic-soda solution, which is delivered through sprays K, from a tank above the kier, and is circulated by means of a centrifugal pump L. Steam is turned on until the pressure reaches 10 pounds, and the process is continued for from 2 to 3 hours, according to the nature of the material. The steam is blown off, which occupies about 15 minutes, the door is opened, the wagons are removed, and another pair run in, the three latter operations occupying only 10 minutes. The rags, after being withdrawn from the kier are washed by flowing water on the top of the wagons. This kier is capable of doing at least 40 tons of rags per week, and it is adaptable to all classes of rags."

36. Among the advantages claimed for the kier are: (*a*) A notable improvement in the color of the rags, both before and after bleaching; (*b*) economy in washing time; (*c*) saving in steam; (*d*) improved strength of fiber; and (*e*) an enormous saving in space—one kier doing the work of several boilers.

37. The possibilities of washing the rag with hot water before its removal from the boiler are worth careful thought. This procedure results in a brighter-colored stock and a considerable saving in washing time in the washing engine, besides making use of the heat in the boiler and rags.

38. Cooking with Lime.—Caustic lime alone is widely used on this continent for cooking new, white cuttings. In the mills making the highest grades of writing paper, where such grades of rags as hoisery clips, white shirt cuttings, etc., are being used, the almost universal practice is to employ lime alone for the cooking. These rags are always clean, and they do not need the severe causticizing action of caustic soda, which has a tendency to make rag stock yellow. The excellent color produced by

cooking with lime is another factor determining its use for that particular purpose. Lime, also, is the cheapest alkali. The usual practice in cooking this grade of rag would be as follows:

For 5 tons of rags 600 pounds of lime would be used. The pressure carried in the boiler would be 30 to 40 pounds, and the cooking time 10 to 12 hours.

In using lime there is the question of just what kind of lime it should be. Careful thought points to the conclusion that there is but one kind of lime, the use of which is admissible,— that is a straight calcium lime. In the manufacturing of sulphite pulp, a lime containing a high percentage of magnesium is sought after and used with good results. For a rag mill no such advantage holds and the presence of any considerable amount of magnesium makes that part of the lime almost useless for cooking rags. Magnesium hydroxide is relatively even more insoluble than calcium hydroxide and its action is almost negligible.

Note.—The time required varies with different lots of rags, according to color, dirtiness, etc., and must be determined by experience. Cooking too long wastes time, steam and sometimes fiber. Too short a cook means more trouble in washing, excessive bleach consumption, and probably a harsh stock for the beater.

39. Cooking with Lime and Soda Ash.—The next general class of rags to be considered includes new cuttings of unbleached or colored material such as blue overall cuttings, unbleached shoe cuttings, shirt cuttings, etc. For cooking this type of rag, a combination of lime and soda ash is generally used. When cooking these rags, it is advisable to keep the chemicals fairly high, to take care of the fragments of cotton seed hull, so often found. The paper maker calls them "shives," and they must be thoroughly cooked to prevent their appearance in the finished sheet of paper. The usual treatment of this type of rag is about as follows:

For 5 tons of rags, use 1000 or 1200 pounds of lime and 300 to 400 pounds of soda ash. The pressure would be carried at 30 to 40 pounds, and the cooking time would be about 15 hours.

40. Cooking Old Whites.—Old rags are divided roughly into two types or classes; one of which is the type known as *old whites*. This class would include the No. 1 whites, the No. 2 whites, and the street-soiled whites. There is some variation in the general practice with regard to these rags. Many of the

mills use lime alone on the better grades, while others use a combination of lime and soda ash. An average procedure might be this:

For 5 tons of rags, use 600 pounds of lime and 50 pounds of soda ash; cook at 25 pounds pressure for 12 hours.

This rag has usually been washed many times before it comes to the paper mill, and, as a result, the natural waxes and resins of the fiber have already been pretty well removed. The purpose of the cooking, then, is to remove the oils, grease and dirt that may be present. This being the case, it would seem that the addition of a small amount of soda ash to the cooking liquor would perhaps be the better practice.

41. Cooking White and Colored Cotton Mixtures.—The other class of old rags is that in which there is a mixture of white and colored cottons, as twos and blues, thirds and blues, etc.

In cooking this type of rag, both lime and soda ash are used. The lime helps materially in producing a good white, and the soda ash is needed to bring up the causticity of the cooking liquor to a point where it will more efficiently attack the dirt and grease present. The usual treatment for this type would be as follows:

For 5 tons of rags, use 1200 pounds of lime and about 150 pounds of soda ash. Cook at 25 to 30 pounds pressure for 12 to 15 hours.

42. Cooking Linens.—In the cooking of linen rags, as in the case of cotton, no general rule can be laid down, as very much depends on the particular character of rags to be cooked. The cooking liquor is either caustic soda or a combination of soda ash and lime. For a new, white linen, free from shives, the cooking treatment is rather mild; 2% of caustic soda, with a pressure of about 20 pounds for 6 hours, would cook the rags thoroughly.

For old linens or new gray linens, which are quite likely to contain shives, a fairly strong liquor of lime and soda ash is needed. Here the pressure would be advanced to 30 to 35 pounds, and the time to 10 or 12 hours.

Note.—**Linen** is composed of the bast fibers of the flax plant, *Linum usitatissimum*. The plant yields about 8% of fiber, which is separated by retting and is then known as *flax*. The ultimate fibers are 6 to 60 mm. long, and are 0.012 to 0.026 mm. wide, the average ratio of length to

width being about 1200:1.   The fibers are thin-walled tubes, with thickened places or knots at intervals; the ends are tapered, the walls rather transparent, and the canal is small.   Two samples of Belgian flax have been found to contain 81.99 % and 70.55 % cellulose.

43. Use of Caustic Soda.—In England and on the continent of Europe, caustic soda is largely used in cooking all grades of rags, lime being recommended only for the very cheapest. The amount of caustic soda used varies from 1 % to 4 % or 5 % of the weight of the rags, depending, of course, on the nature of the rags to be cooked.   It is well adapted for rags containing albuminous and starch sizings, and it readily attacks oil, grease and dirt.   The rags are easily washed, and they make excellent rag pulp.   It is generally recognized, however, that cooking with lime will give a pulp of better color.   If the question of cost is to be considered, lime is cheaper by far than the caustic soda.

44. Variations in Cooking Practice.—To date, there is no definite evidence as to the comparative strengths of rags cooked with lime as against those cooked with caustic soda.   The fact that both processes are in excellent repute leads to the belief that no great difference will be found one way or the other. There is considerable variation in practice among the different mills with regard to the cooking pressure and the duration of the cook.   In some mills, the practice is to cook at a high pressure and for a short length of time, while in others, this practice is reversed.   It is very seldom necessary to exceed a pressure of 40 pounds or a cooking time of 18 hours.

Whatever the practice of the particular mill, it is generally agreed that rags should be thoroughly cooked.   Well-cooked rags wash easily, bleach easily, and produce a whiter pulp. They respond better to treatment, and produce better and more nearly uniform paper.   It is a mistake to undercook rags, with the idea that they will produce a stronger or more durable paper.

WASHING RAGS

45. The Washing Engine.—Fig. 10 is a plan and longitudinal section typical of the Hollander type of washing engine, which is most common.   It consists of an open tub A, in which the rags and water circulate.   The circulation is maintained by the roll R, which throws the rags over the back-fall B.   In front of the roll,

shown in section, is the button catcher C; this is a recess in the floor, covered by a metal grid, and its purpose is to catch any buttons, metal, sand, etc. that may still be in the stock. In many cases, a second button catcher is installed just behind the back-fall. The roll, or fly, bars J are set about 3 inches apart in notches in the circumferences of three disks, keyed to shaft S, and the spaces are filled with wedges of wood. The bed plate P is made up of metal bars interspaced with wood. For a washing engine,
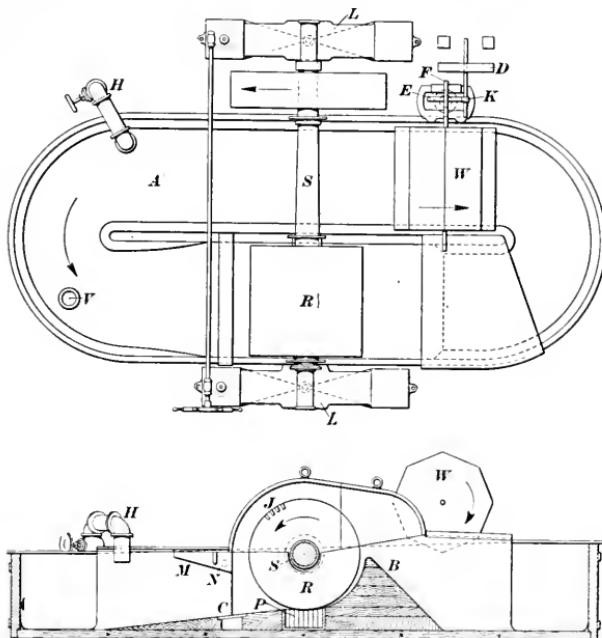

Fig. 10.

bed plate should be of the type that the paper maker calls a *slow* the *plate*, say $\frac{1}{4}$ or $\frac{3}{16}$ inch bars and $\frac{1}{4}$ or $\frac{3}{16}$ inch wood. The roll, making 90 to 100 r.p.m., or even 120 r.p.m., draws the rags over this bed plate and draws them out; *i.e.*, unravels the weave. At some point like V (shown in the plan) is a valve for dumping the washer. L, L, are the **lighter-bars** (levers), on which the roll bearings rest, and by means of which the roll is raised or lowered through the action of a worm gear and screw, described in detail in the Section on *Beating and Refining*. A hydrant, situated at H, is the means of furnishing water to the washer. For washing oily rags, where much foam is produced, the foam may be skimmed off by a strainer of coarse-mesh wire M, which

allows the foamy water on top to pass out the outlet N, retaining the rags. W is the washing cylinder described in Art. **46.**

46. Fig. 11 shows the principle and construction of a washing cylinder. Two octagonal wooden heads A_1 and A_2 are carried by the shaft B; A_1 is fastened to the shaft by a spider, which gives an outlet through the sleeve C. Both heads are slotted radially, as at D, from the center to each vertex (corner), and also from each vertex perpendicular to these slots, as at E. Boards F are slipped into slots D, meeting at the center, and ending flush with slots E. Boards G fit slots E, and are planed at the edge flush with the sides of the octagons, leaving a space
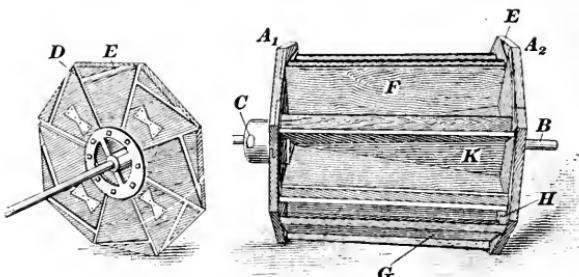

Fig. 11.

H for water to enter as the drum turns. A fillet K deflects the water to the outlet C as each pocket rises. Wooden gratings, covered with copper or bronze wire screen of 50–60 mesh, are screwed to the heads and complete the cylinder; the screen prevents much loss of fiber, though some short ones get through. The cylinder W (Fig. 10, which also see) turns at the rate of about 12 r.p.m., being lowered by a ratchet so that a gear E on shaft F engages a pinion K made fast to a pulley D, which is driven by a belt from the roll spindle S. A washing engine may carry from one to four of these drums, as may be necessary.

Another type of washing apparatus is shown in the Section on the *Treatment of Waste Papers*.

47. After the rags leave the boiler, they are usually allowed to stand in the cars for 24 hours. Evidence has shown that by standing in this way, the dirt is more readily washed out, and a better color is obtained on the half-stuff. Before the rags are furnished to the washer, some sort of a foam killer should be added, especially in the case of rags cooked with soda ash or caustic soda. A pint of kerosene oil to each 300

pounds of rags is as effective as most of the prepared or patented foam killers.

48. The Washing Process.—The washing engine is partly filled with water, the roll taken up well off the bed plate, and the rags furnished, meanwhile adding water gradually. Soon after the furnishing is completed, the washing cylinder is let down, and the hydrant valve is so regulated as to give all the water the cylinder can take out. For the first hour, the engine should have plenty of water, and the roll should be kept well off the plate, so that it is just brushing the rags. Putting the roll down too soon will rub the dirt into the fibers, and the result will be poor color. After an hour's washing, the color will usually be such that the washerman can begin to bring down his roll and take the fiber out of the rags. This must be a slow process, and the roll should be lowered gradually and often instead of *vice versa*. As the washing progresses, the amount of wash water may be reduced, especially if it is necessary to supply a maximum to another washer that has just been furnished. The rags are washed until the effluent is practically clear, and until the fibers are well drawn out of the rags. Care must be taken not to cut the fibers, for long half-stuff is much better than short half-stuff; the beaters can shorten the fibers, but can't make them longer.

49. Discussion of Washing.—An important consideration in the paper-making process is the water. Cellulose readily absorbs organic coloring material from it, and becomes yellowish; iron is sure to cause discoloration in white or delicately tinted papers. One hundred gallons a minute is a very reasonable amount to use in a thousand-pound washing engine. This means a lot of water; and if organic coloring materials are present in quantity, there is a marked effect on the color of the half-stuff. Clean, colorless water is a necessity where fine papers are made.

The time given for washing the various grades or classes of rags runs from $5\frac{1}{2}$ or 6 hours to perhaps 14 hours, in a few extreme cases. In the case of linens, white shirt cuts, hoisery, etc., the length of treatment is determined by the time needed properly to draw out the fiber; 8 to 12 hours covers the range in this class. For such rags as overall cuttings and the like, 8 hours is a fair length of time. In the case of old rags, the time needed to wash them clean is an important factor. For thirds and blues, 6 hours is the usual time.

In all the above cases one hour is allowed for bleaching after the washing itself is finished, and bleaching is the next subject to be considered here.

QUESTIONS

(1) Name the three kinds of liquor used for cooking rags, and give the molecular formulas of the chemicals in each.

(2) Mention an advantage and disadvantage of each kind of cooking liquor.

(3) How is cooking liquor prepared?

(4) What kinds of rags are best cooked with (a) lime?   (b) lime and soda ash?   (c) caustic soda?

(5) Why should rags be thoroughly cooked?

(6) (a) What are the principal features of the washing engine?   (b) State the function of each.

BLEACHING, DRAINING, AND LOSSES

BLEACHING

50. Theory of Bleaching.—In the process of bleaching, the impurities that cover up the natural whiteness of the cotton fiber are oxidized and removed; the fiber itself will stand the action of reasonable bleaching without being impaired.

While there are many possible bleaching agents, chlorine or a chlorine salt is the most economical, and is the one generally used. The bleaching, or oxidizing, is not due primarily to the action of the chlorine, but rather to the fact that the chlorine reacts with water, liberating oxygen. This oxygen attacks and destroys nearly all coloring materials and impurities, changing them to colorless or soluble substances, and restores to the cellulose its natural color. A slight yellow color can be compensated for by proper dye-stuffs. Taking, for example, the case of bleaching powder, which is most used, this reacts somewhat as follows· (See Sections on *Elements of Chemistry*, Vol. II, and *Bleaching of Pulp*, Vol. III): In solution in water,

$$2CaCl(OCl) \rightarrow Ca(OCl)_2 + CaCl_2;$$

then,

$$Ca(OCl)_2 + 2H_2O \rightarrow Ca(OH)_2 + 2HClO,$$
$$2HClO \rightarrow 2HCl + 2O(\text{nascent}),$$
$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O.$$
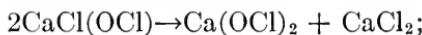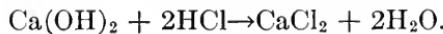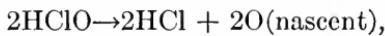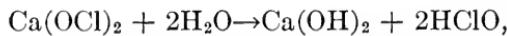
The final products of the bleaching powder are, then, calcium chloride and oxygen in the nascent state.   The oxygen unites with the impurities to form less objectionable compounds.   The action of liquid chlorine is very much the same; the final products being oxygen and hydrochloric acid.   The intermediate reaction is:

$$H_2O + Cl_2 = HCl + HClO.$$
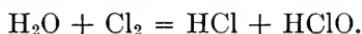
Soda ash is usually added to neutralize the hydrochloric acid so formed, giving NaCl and H_2O and CO_2.   It is to be noted that acids are injurious to the fiber, and that they affect some coloring matters.

51. To get the largest yields in the preparation of bleach liquor from bleaching powder, special care must be given to the process. Yields of 85% to 95% of the actual available chlorine present are possible, but yields of 60% to 80% are, unfortunately, rather common.   One of the first things to determine is the strength to which the liquor shall be made up.   A few minutes thought will prove that the lower the Baumé test of the liquor the more water may be used in washing the sludge and the higher will be the yield.   On the other hand, the Baumé test must not be run too low, because of the greatly increased storage facilities needed.   A liquor testing 4° Baumé is perhaps the most economical.   The sludge remaining in the settling tank should always be washed once, perhaps twice; the latter is usually possible only when the liquor that results from the second washing can be used with new bleaching powder, to prepare the strong liquor.

52. Preparation of Bleach Liquor.—The method of preparation of bleach liquor is briefly as follows:

The powder and either wash water or fresh water are put into a tank having a mechanical agitator, like an ice-cream freezer, or like the vertical stuff chest shown in the section on *Beating and Refining*.   The whole is mixed, and the lumps are thoroughly broken down.   This mixture is then pumped to the settling tank, where as much water as is needed is added.   The minimum settling time for reasonable yields is 24 hours, and wherever possible, 48 hours should be allowed.   This liquor may then be run off from the sludge into the storage tank, using either wash liquor or water, as the case may be, to bring it to the required degree Baumé, *i.e.* the desired chlorine content.

Extreme care must always be taken to see that the liquor in the storage tank is clear, which means that a high calcium lime should be used for making the bleaching powder. A bleach liquor that is turbid, due to carelessness in running from the settling tank, will lose much of its action in the washer.

53. The Bleaching Process.—Before adding the bleach liquor to the washing engine, the roll should be taken up off the plate, the wash water turned off, the excess water removed, and the washing cylinder raised. The bleaching liquor may then be slowly added. The usual practice in American mills is to add an acid substance as an accelerator, after the bleaching liquor is in; this must be done with great care. A few pounds of alum to each washer makes a very good accelerator, and is safer than acids, such as acetic acid, but especially HCl and H_2SO_4. It assists in converting the $Ca(OCl)_2$ to HClO. The use of an *antichlor* is common in neutralizing occasional excess of bleach; but it cannot be unqualifiedly recommended, because, in most cases, the cure is as bad as the disease. Sodium hyposulphite, sodium sulphite, and calcium sulphite have all been used, usually in the beater, and many others have been suggested and tried. The use of antichlor, however, is becoming more and more the exception in the bleaching of rags. The bleaching may also be hastened by warming the stock. This may be done by blowing in steam before adding the bleach; the temperature should not exceed 100°F.

After the rags have been brought to color, the excess chlorine should be washed out by lowering the washing cylinder and turning in fresh water. A very slight excess may be left to spend itself in the drainer.

There is a further method of washing the excess chlorine from the rags, which gives excellent results. When the bleaching is nearly complete, the rags are dropped into the drainer. After the drainer is filled, 12 hours is allowed for the rags to come up to color. At that time, two or three washers of water are put down on the drainer of half stock.[1] This process is repeated 12 hours later. In this way, practically all traces of chlorine are removed.

54. Use of Liquid Chlorine.—During the last few years, the use of liquid chlorine for bleaching rags has been demonstrated as a commercial possibility; and it now seems likely that within

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[1] **Half stock** or **half-stuff** is defibered raw material that is ready for the beater. See Art. **27.**

the next five years its use will become quite general, since it is both convenient and more economical than bleaching powder.

The only apparatus required in order to use it is that for transferring it and measuring it into the washing engine. A scale

Check Valve

Solution Line To Bleaching Tanks
Chlorine Back Pressure Gauge
Chlorine Control Valve
Manometer For Chlorine Meter
Chlorine Shut Off Valve
Chlorine Blow Off Line
Steam Exhaust Line
Chlorine Pressure Reducing Valve
Tank Pressure Gauge
Manifold

Compression Chamber
Vacuum Relief Line
Solution Back Pressure Gauge
Manometer For Solution Meter
Solution Control Valve

Water Pressure Reducing Valve
Strainer
Chlorine Cylinders
Cold Water Supply Line
Blower

ELEVATION

Thermostat
Automatic Steam Valve
Waste Line
Steam Supply Line
Steam Control Valve To Manifold
Circulating Pipe
Evaporator Tank
Steam Shut Off Valve
Overflow

Bleaching Tanks
Solution Line

Blower

Platform

PLAN
FIG. 12.

for weighing the container, and an injector, accomplishes this readily. Fig. 12 shows a diagram of a typical installation.

55. In using liquid chlorine it has been found that the white produced on the half-stuff has a slightly reddish tinge, which replaces the slightly yellowish tinge that is produced with bleaching powder. This, however, can be easily corrected in coloring.

Soda ash is generally added, to neutralize the HCl formed in the bleaching reaction; otherwise, the acid would attack the fiber, the steel of the beater roll, and the paper machine. Experience has shown that a pound of chlorine gas will do the work of about 10 pounds of bleaching powder, which may be figured roughly as one-third chlorine; it is always ready for use, and no mixing and settling tanks are required.

56. Amount of Bleach Needed.—The amount of bleaching powder required in bleaching rags naturally varies considerably, both with the color of the rag before bleaching and the color to which it is desired to bring the rag half stock. For new white cuttings, the amount of bleach used is about 1%, or 10 pounds of bleaching powder in solution for a thousand-pound washer. At the other extreme, for such rags as Thirds and Blues, from 5% to 6% of bleaching powder is generally used.

DRAINING

57. The Drainer.—When the half-stuff in the washing engine has come up to color and the chlorine is washed out, the valve
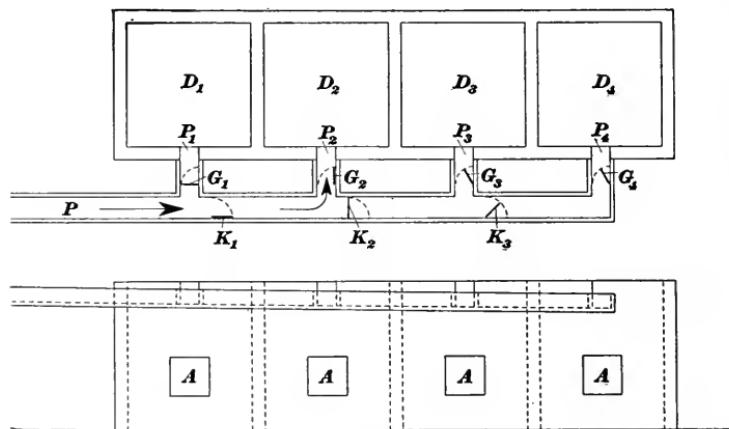

Fig. 13.

in the bottom of the engine is lifted and the last of the material is raked down to the valve, whence it flows into the drainer through a system of pipes and valves, Fig. 13. D_1, D_2, etc. are drainers. The stock comes down in pipe P. To fill any drainer, as D_2, all preceding side pipes, P_1, etc., are closed by valves G_1,

etc.; G_2 is opened and the main pipe closed as at K_2, preventing stock for drainer D_2 from filling the remainder of P and later passing to another drainer. The pipe line is often a plain wood box. Sometimes the gates G_1, G_2, etc. are hung so as to swing across either the main channel P or the side channels, P_1, P_2, etc., thus eliminating gates K_1, K_2, etc.

The purpose of the drainers is well expressed in the name; *i.e.*, they allow the water to drain from the stock and to take soluble impurities with it. In addition to this, the drainer also provides for rag half-stuff, storage sufficient to take care of the necessary variation between the consumption and production.

The drainer is a small room, which may be 20 feet long by 8 to 10 feet wide, and about as high. It is of masonry construction throughout, except for a wooden door A (Fig. 14). This door is an opening in the front of the drainer; it is about 3 feet square, and about 3 feet from the floor. Fig. 14 shows how the floor of the

Fig. 14.

drainer is constructed. When the special tile (perforated with holes wider at the bottom) is used, the false floor is laid on concrete, with a slight slope to a main drain.
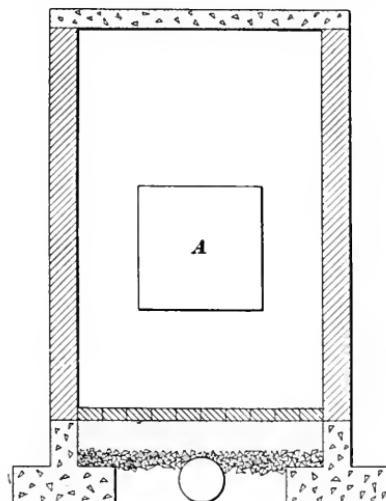
58. Time that Stock Is in Drainer.—Rag stock should usually be left in the drainers for two to three weeks for best results. It is possible to use the stock in a shorter time, and, in the exceptional case, stock may stay in the drainer for several months. In the latter case, however, it is usually advisable to freshen the stock by letting a washer of water and bleaching liquor down on top of it. This helps materially in the subsequent use of the stock.

The possibilities of washing the stock in the drainer by putting down washers of water on it, have been discussed fully above, and the subject need not be given further consideration here. Care must be taken that as each kind of stock comes through from the boiler, a drainer is empty and clean, ready for it.

59. Possible Use of Wet Machine.—It has often seemed that it might be possible to adapt a wet machine (used for de-watering wood pulp, as described in the Section on *Treatment of Pulp*) to this problem of draining rag half-stuff. If this could be accomplished, many advantages would be gained. The half-stuff could be taken from the machine in laps of uniform moisture content, and the question of weight on rag half-stuff (a rather dubious figure in most mills) could be settled. The rags might
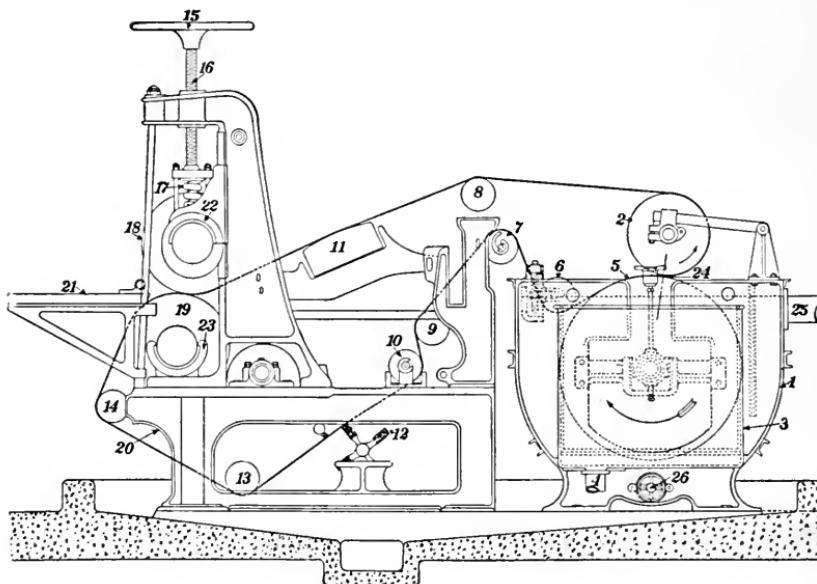

Fig. 15.

be piled directly on skids, and these, wrapped if necessary, could be put in storage, in the same manner as pulp. The writer feels that this method would keep out much of the foreign dirt that is occasioned by handling the stock from the drainers to the beaters in stock cars. In addition to this, a much more rigid inspection of the product would be possible, since many of the troubles would show up at once on the wet machine and not at the end of the paper machine.

Fig. 15 illustrates a wet machine. The thin stock enters the vat 1, through pipe 25; 26 is a washout. The cylinder 5 collects fibers from the stock as water passes through the screen surface of the cylinder and out at 3 and 4. An endless woollen

felt, pressed down by the couch roll 2, takes the layer of fiber from
the cylinder, carries it over the suction box 11 and between the
press rolls 18 and 19; it winds up on 18, is cut off when
the layer is right thickness, and is folded into a bundle or lap on
table 21. Pressure on roll 18 is adjusted by two mechanisms
15, 16, 17. The felt is carried on rolls 6, 7, 8, 9, 10, 13, and 14,
and is washed by a shower and whipper 12. A lap from a 72-inch
machine will weigh about 50 lb., and will contain about 30% to
35% of fiber.

The practical questions are of course whether the long rag
half-stuff could be handled by a wet machine satisfactorily,
and whether the full bleaching effect of the chlorine would be
obtained in the shorter time of contact.

LOSSES IN THE PROCESS

60. Total Losses.—In each step in the preparation of rag
fibers, there is an attendant loss in weight. Roughly the weight
of half-stuff will run from 65% to 80% of the weight of raw
material purchased, depending of course on the grade of rags in
question and the care used in the processes of treatment. There
is also a considerable loss in weight in storing rags. Rags in
storage for several months will lose up to 4% in weight. This is
almost entirely a moisture loss, and it is probably fully regained
in the processing.

61. Losses in Detail.—The first actual loss comes in the
removing of the tare (wrapping). Under trade customs, this is
limited to 3%, and, usually, it will not average quite as high as
this. Any tare in excess of 3% is chargeable to the dealer from
whom the rags were purchased.

62. There is some loss in the rag thrasher. In the case of new
cuttings, this would probably be very slight—not over $\frac{1}{2}\%$.
On street or dump rags, however, losses here amounting to as
high as 10% or more are not unusual. In the case of cleanly
packed Thirds and Blues, the loss here will usually be close to
2%. The dust from the thrashers consists of dirt, buttons, etc.,
with considerable fiber dust, which is thrashed out. Such dust
is salable to roofing mills and to mills making some of the lower
grades of coarse papers; it is usually called a **No. 2 dust.**

63. The next loss to be considered is the sorting loss. This, too, depends very largely on the grade of rags being sorted. New cuttings may run as low as 1% or 2%; while in the case of old rags, this loss will run from 5% up, depending on the quality of the rags. In the case of thirds and blues, from 5% to 6% is about the loss to be expected where the best rag obtainable is used. The out-throws are largely what is known as *muss*. This consists of strippings, seams, etc., in short, such material as must be thrown out of the rags being sorted; it contains metal and rubber in abundance. Material that is sorted out because of its color goes into what is known as blacks, and this consists of hard or fast colors (as red and yellow) and blacks. As in the case of the dust, this material is readily salable to lower grade mills, and is used in the manufacture of certain of the cheaper grades of coarse papers and roofing papers.

64. There is a further loss at the rag cutter, which is practically constant, regardless of the grade of rags being cut; it is due to the dust formed by the cutter knives, which is separated from the rags by the dusters at that point. The loss in dust at this point will run from 1% to $1\frac{1}{2}$%, depending somewhat on the equipment used. This form of dust is called **No. 1 dust;** it is much superior to No. 2 dust, being fairly clean and consisting largely of short fibers.

65. In determining the losses due to cooking, washing, and bleaching, these three processes are usually linked together, because of the difficulty of arriving at the weight and consequent losses at any intermediate step. Moreover, these yields are always rather difficult to determine accurately, even though one considers the three processes together; for the rag that is once wet in the bleach boiler is not dried out again until it gets into paper. At their best, then, these figures are not any too accurate.

66. In the case of new cuttings, a yield of 85%, based on the weight of the dressed rags, is a figure that is fairly accurate. This figure would of course be too high in cases where the rags were heavily loaded with starch or other material.

In the case of such rags as thirds and blues, a yield of 75% to 80%, based on the dressed weight of the rags, is about what should be expected. For street whites, however, this yield would be considerably lower, and would be nearer 60% than 75%.

Many things may come into individual lots or types of rags that would change these yields entirely. For the general run of rags, however, they should prove out fairly accurate.

QUESTIONS

(1) (*a*) What bleaching agent is generally used for rags? (*b*) how does it act?

(2) How can an excess of bleach be gotten rid of?

(3) As regards purpose and manipulation, compare the drainer with the wet machine.

FIBERS OTHER THAN RAGS

HEMP, JUTE, SEED-HULL FIBER, ETC.

HEMP

67. Use and Importance.—By far the most important of the **hemp** fibers used for paper making is the *manila hemp*. This fiber is used very largely by a group of mills known as makers of rope papers.

The largest tonnage of these papers goes into sacks, the first in importance being flour sacks, but also including sacks for sundry uses, such as cement, lime, plaster, etc. The manila-rope fiber is used on account of its great fiber strength; also, for the pliability of the product which it produces.

Manila-rope papers used for cable insulation purposes probably rank next in importance. The copper conductors in power cables are insulated by a number of wraps of rope paper, slit in widths from $\frac{7}{8}$ inch to 2 inches, after which, the whole cable is saturated with insulating oil compounds. In telephone cables, the fine conductors are insulated with a single thickness of very thin manila paper, which is left dry in the final cable. Other uses of manila paper are for sand paper, shipping tags, gaskets, pattern paper, and the like.

Note.—**Hemp** (*Cannabis sativa*). The fiber is prepared by retting, from filaments that run the entire length of the stem. The ultimate fibers composing these filaments vary from 5 to 55 mm. in length, averaging 22 mm. in length and 0.022 in diameter. The ratio of length to diameter is, there-

fore, about 1000:1. The fibers have very thick walls, which are not very highly lignified. The ends are large and sometimes flattened, and the central canal is almost obliterated. In microscopic appearance, the fibers are very similar to those of flax; but they differ from linen in having greater ability to break down into fibrillæ (fibrils) during the mechanical process of paper making. Müller gives the cellulose content of a sample of raw Italian hemp as 77.13 %. Many other plants yield fibers to which the name hemp is given; but they are generally distinguished as manila hemp, sisal hemp, sunn hemp, etc.

Manila hemp (*Musa textilis*). Manila hemp is prepared from the outer sheath of the stems of the musa, which is a species of banana. The ultimate fibers are from 3 to 12 mm. long, averaging about 6 mm. The width varies from 0.016 to 0.032 mm., averaging 0.024 mm., the ratio of length to width being about 250:1. The fibers taper very gradually toward the ends; the central canal is large and very prominent, while fine cross markings are numerous. The percentage of cellulose in raw manila is given by Müller as 64.07 %.

Agave. Among the most common of the fibers of this class is sisal hemp, or heniquen, which is largely employed for cordage, bags, etc., in which forms it reaches the paper mill. The ultimate fibers are longer than manila fibers, rather smaller in diameter, tapering and pointed at the ends, and comparatively stiff. The central canal is not prominent, but can be seen as a narrow line in some of the fibers. The walls are thick; they are characterized by many fine cross lines, close together, which are found on nearly every specimen.

68. Source of Supply.—The manila fiber used in these papers is practically confined to old manila rope. The old rope is collected by junk dealers, usually sold by them to larger dealers, who, in turn, sell it to the rope-paper mills. Such old rope is usually collected at definite places; such as sea ports, important lake or inland shipping points, gas- and oil-well districts, etc. A very considerable amount of old rope for paper making purposes is imported into this country from European points. The manila fiber for rope making comes from the Philippines, and it represents one of the principal products of these Islands.

69. Preliminary Treatment.—The rope is inspected, first, on being unloaded and, again, and more intimately, at the rope cutters, where any foreign material or fibers other than manila are thrown out. The rope is cut by what is known in the trade as *rag cutters*, but the knife equipment of these is so modified as to produce longer pieces. The length of the manila threads after passing through the rope cutter ought to be about 2 inches. The cut rope then goes through rotary dusters, which open up the fibers and eliminate much of the loose dirt.

70. Cooking.—From the dusters, the cut rope is then fed into the rotary boiler. This is the same type of boiler as is in general use for cooking rags, and it holds approximately 5 tons. The cooking liquor is made from lime and soda ash; and, as is the case with rags, the strength of the liquor, the time of the cooking, and the steam pressure vary with the results to be obtained and the characteristics of the particular lot of rope at hand to be cooked. Average conditions would be about as follows:

For a 5-ton boiler, use 1000 pounds of lime and 500 pounds of soda ash; cook at 25 pounds pressure for 10 hours.

This cooking process removes the natural waxes and loosens up the foreign dirt and grease. It makes the fiber softer and more pliable, and greatly improves its working qualities.

71. Washing and Bleaching.—The washing and bleaching are usually done in the beater, that is, as different parts of the beating process, without recourse to the half-stuff, or ordinary, method of treatment. The rope-paper mills generally use beaters of from 800 to 1300 pounds capacity. Ordinarily, the cooked fiber is furnished directly to the beater; and the washing cylinder is lowered and the washing process is carried out in much the same manner as rags are washed in the washing engine. When the washing is completed, the bleach is added. After bleaching, the washing cylinder is again lowered, and the excess of bleach is washed out. From this point, the ordinary beating process is continued. The amount of bleach is quite low, as a pure white is not attainable and is never attempted. Moreover, a great many of the papers are entirely unbleached; but if bleached, the usual quantity of bleaching powder consumed is from 5% to 10% of the weight of rope furnished.

72. Yield.—The yield of manila rope as bought, compared with the amount of paper made, will run about 50% to 65%, depending on the thoroughness of the cleaning, cooking, and bleaching treatments. It can be readily seen that a satisfactory paper for cement sacks can be produced with much less cleaning than is required for a light-weight, telephone insulating paper.

Mention should be made here of the use of *true hemps*, which are employed in Europe for certain special papers, such as Bible, cigarette, etc. The true hemp is prepared by methods described; but in the beater, it acts like linen, the fiber splitting

longitudinally into fibrils which can be felted into a sheet possessing exceptional formation, strength, opacity, and finish. This fiber bleaches to a much better color than manila hemp.

JUTE

73. Use and Importance.—The **jute** fiber is the isolated bast of the jute plant, which is an annual of very rapid growth, attaining a height of 8 to 10 feet in the hot Indian climate. To obtain the bast fiber, the plants are cut down and steeped or *retted* in a pool of stagnant water. By this means, a fermentation process is started. When the retting is completed, the bast layer (which is between the bark and the wood) is stripped off and washed, and goes in this form to the textile mill, where the fiber is spun and woven into twine or burlap.

Jute fiber is extensively used in the manufacture of wrapping paper; it produces paper of excellent strength and durability, being second only to hemp. Attention must be called at this point to the fact that jute is not a pure cellulose fiber, being what is termed a ligno-cellulose, and it is used as such in paper making. On this account it bleaches to a bright yellow color, and this, of course, places certain limitations upon its use. The fiber is also used to some extent in buff drawing paper and other papers of that type.

74. Source of Supply.—As is the case with cotton, the raw fiber is much too high in price to permit of its direct use by the paper maker. Moreover jute cloth goes almost exclusively into sacks and other articles, which are cut without waste, so that now cuttings of jute are not on the market. This limits the supply of the paper maker to old sacking, burlap, and string, and practically all of the jute used is from this source. As is the case with rags, it is collected and sorted and turned over to the paper maker in bales.

The fiber from the butt of the jute plant is not suited to spinning; and a few years ago, these jute butts were used to a considerable extent by paper makers. This stock is very dirty and not particularly desirable, and its use is considerably restricted.

NOTE.—Jute (*Corchorus capsularis* and *C. olitorius*). The fibers of jute are about 2 mm. long and 0.022 mm. in diameter. They are thick-walled; the central canal is very variable, at times being of considerable width and then

narrowing to hardly more than a line. The surface is quite smooth, and there may be noted at intervals radial canals and joints, which are similar to those in linen, though not so pronounced. Jute contains about 63% cellulose and 24% ligno-cellulose. As exported, the composition of the bast varies, the fiber content ranging from 49% to 59%.

75. Preliminary Treatment.—The preparation of jute for paper making varies considerably with the particular type of paper that is to be made from it. Obviously, in the case of a high-grade drawing paper, much more care must be taken in the sorting, washing, and bleaching than would be the case when a much cheaper product, such as wrapping paper, is to be made. In the former case, the jute bagging is put through the thrasher; it is then sorted over rapidly by women, who take out the foreign material that may be present and any pieces of rotted bagging. The stock is then ready for the cutter, where it is cut, dusted, and delivered to the boiler for cooking. The ordinary type of rag cutter and duster is used, and the boiler is the cylindrical rotary, in nearly all cases.

76. Cooking.—The reasons for cooking jute are similar in many respects to the reasons for cooking rags. The cooking removes the foreign dirt and loading and the natural waxes of the fiber, leaving it in such condition that it responds readily to subsequent treatment. In cooking jute, no attempt is made to cook out the lignin—the object is simply to prepare a ligno-cellulose fiber for use as such in the paper-making process. This being the case, it is the practice to use fairly low temperatures or pressures, say, 20 pounds. The cooking time most commonly used is about 10 hours, although this may be varied 2 hours either way in the different mills.

It is the almost universal practice to use lime as the cooking chemical. While the quantity varies somewhat with the condition of the stock and the result desired, the usual practice is to use from 10% to 20% of lime.

77. Washing and Bleaching.—In general, jute is washed and bleached by the same processes as rags. In most cases, however, the stage known as half-stuff is omitted, the washing and bleaching being done as a part of the beating process. That is, instead of dropping the stock into the drainer after it is washed and bleached, the beating operation is continued in the same engine, without interrupting the process. In this case, the stock is furnished into

the engine after it has been cooked and is then throughly washed with the washing cylinder.   When the washing is complete, the bleaching liquor is run in, and the stock is allowed to bleach up to the desired color.   Dry bleach is often added directly to the engine when bleaching jute.   It is usual to "sour" with a little H_2SO_4 to hasten the bleaching action; but free chlorine may form yellow lignin chloride.   The excess bleach is then washed out with the cylinder washer; and from this point, the beating operation proper begins.

In bleaching jute, about 8% of bleaching powder, figured on the dry weight of the fiber, is used, and the stock comes up a bright yellow color.   Liquid chlorine cannot be used successfully, as the bleaching solution must be alkaline.

78. Yield.—The yields from the jute fiber vary considerably, depending on the care with which the preparation of the fiber is conducted and the degree of washing and bleaching.   Since the half-stuff or intermediate form is usually omitted, it is convenient to consider the yield of paper from the baled weight of the jute; in the average mill, this yield varies from 50% to 65%.

SEED-HULL FIBER, BAGASSE, ETC.

79. Cotton-Seed Hulls.—When the cotton seed comes from the cotton gin, there is left on it a fuzz of short cotton fibers, firmly attached to the seed.   This will amount to approximately 200 pounds of fiber per ton of seed.   It has long been the practice to cut off from 60 to 75 pounds per ton of seed, as a first cut, for use in making mattresses; the remainder went into the meal used for cattle food.   As a development of the war, it now seems entirely possible that the second cut, hull fiber or linters, from the cotton seed may be made available for use in paper making.   Little can be said as yet about this source of raw material, as the first mills for its preparation in quantity are just beginning operation. From figures now at hand, several hundred tons per day may become available, if the experiment is a success.   Just how, when, and where the paper maker will use it remains to be seen, and much depends on what can be done with it after the preparation problem is thoroughly worked out.   It now seems likely, however, that its place will be as a substitute for soft cotton rags, such as thirds and blues.

80. Preliminary Treatment.—A brief outline of the present ideas as to how this material should be handled follows:

The seed is first thoroughly cleaned and all foreign dirt is removed; after which, the first cut is made, say of 75 pounds per ton of seed. The seed is then cut, and the kernels are separated from the hulls. The latter are treated in a steel attrition mill for the removal of the fiber, and the fiber and hull bran are separated by proper screening.

81. Cooking.—The next process is the cooking. The cooking liquor used is caustic soda, and a fairly high concentration is necessary, say about 20% on the weight of air-dry fiber. Experiments so far indicate that a high pressure is needed (about 80 to 100 pounds), and that considerable care must be taken to insure proper circulation of the liquor in the boiler. The cooking time depends largely upon how rapidly the digester can be brought up to temperature, and it will probably be found that 6 to 8 hours will be the right length of time.

Little can be aid as yet with regard to the type of boiler that will be used for this work. To date, experiments have been largely with the soda-pulp digester. There are two difficulties to be overcome with the ordinary soda digester, however; the first is that of circulation of the cooking liquor, and the second is the difficulty of blowing the cook. Very few of the cooks of this material in the usual soda digester will blow clean.

How the further preparation will be carried out is also rather a question. The cooked fiber must be washed and bleached. It will probably not be possible to screen it as a part of its preparation because of the very nature of the fiber. This makes it all the more necessary that it be thoroughly cooked, so that the bleaching process may destroy all the seed-hull fragments that are left in, and which would make dirt in the paper. Several mills are said to be using hull fiber and linters with good results, but details of their methods are not available.

82. Use in Paper Making.—The use of this material on any extensive scale in the paper industry depends on two factors: first, whether it can be so handled by the paper makers that it will produce the same strength, tear, and folding endurance that are obtainable with soft rags; second, whether it can be profitably produced in competition with soft rags over a period of time.

83. Bagasse.—The crushed stalks of the sugar cane, known as **bagasse** or **begass,** have been proposed many times as a possible source of paper-making raw material, and this material has been tried out on several occasions.   It is first run through the cutter, and is then cooked with caustic soda.

The pulp is easily reduced, and is readily washed and bleached. The yield of pulp from the dry stalk is very low, from 20% to 30%. This fact, together with the fact that it is generally rather dirty, and that it may usually be more economically used for fuel on the plantation, has made its use very limited.   In character-istics, it resembles straw pulp rather closely.   An interesting use of bagasse paper is in covering young plants.   The cane, or pineapple, pierces the paper, while weeds are smothered, and moisture conserved.

84. Miscellaneous Fibers.—Almost any fibrous raw material can be used in the manufacture of paper; consequently, there are many other fibers, the preparation of which might be outlined. Most of these fibers are seldom, if ever, actually used in making paper, however, and the general method of preparation is appli-cable to all.   First, clean the fiber thoroughly; then cook it with an alkali; then wash and bleach it, and it is ready to be made into paper.   Among others, the following deserve mention; papyrus, ramie, China grass, New Zealand flax, saw grass, flax straw and the paper mulberry-tree fiber of the Japanese.   Corn and cotton stalks have also received some attention in the United States; there is a possible field of usefulness for them as fillers.   Corn stalk fibers are very similar to those of bagasse.

ESPARTO

By James Beveridge

HISTORY AND OCCURRENCE

85. History.—**Esparto** was introduced as a paper-making material and as a substitute for rags in 1856 by the late Mr. Thos. Routtcop, a North of England paper manufacturer.   Since then, it has found much favor in England and in other European countries, owing to the quality of the fiber it yields, which is specially suitable for the manufacture of high-class book or

printing papers and medium-class writing papers. Printing papers made from it are of a soft, impressionable nature, yielding clear impressions from type and blocks. It is largely due to this property that the printing and book papers of the highest class in England are so distinctive in character.

86. Where Grown.—The grass occurs in Spain and Northern Africa; it resembles in form a stout wire, tapering to a fine point at the upper end, and varying in length from 12 to 30 inches. Owing to the demand, attempts have been made to cultivate it; but it grows wild, covering large areas in close proximity to the sea coast, and is somewhat easily obtainable. It is pulled (not cut) and harvested by the natives, packed in large pressed bales, and shipped in this form. It differs in quality, according to locality and selection, its price being regulated accordingly. These qualities take the name of the district or Port from whence they are shipped, such as Tripoli, Sfax, Oran, Gabes, etc., in Northern Africa. The Spanish variety, however, is considered the best, although now very limited in quantity, and it commands the highest price. This grass is fine, of a bright russet-yellow color, free from the green chlorophyl when well matured, and yields the highest percentage of fiber. On the other hand, the varieties from Northern Africa differ widely. Some are green, coarse, and unripe, yielding a lower percentage of fiber, and are more difficult to reduce to pulp and to bleach. The additional expense incurred in this treatment naturally reacts on their market value. From whatever source obtained, it is recognized that the fine, well-matured, or ripe grass is more easily reduced to fiber than the coarse, green, and unripe variety; in that it requires less chemicals and yields more finished paper. Esparto should always be kept under cover in a dry place, as it is apt to heat and rot, if allowed to get wet.

NOTE.—**Esparto** (*Stipa tenacissima* and *Lygeum spartum*). The bast fibers are grouped in bundles or filaments, which are resolved into ultimate fibers by the chemical processes employed. The fibers are shorter and more even than those from straw, averaging about 1.5 mm. in length, and the central canal is nearly closed. Serrated cells are numerous, but are considerably smaller than those from straw, while the smooth, thin-walled cells are absent. The chief characteristic that distinguishes esparto from straw and other fibers is the presence of small, tear-shaped cells derived from the hairs on the surface of the leaves. Cross and Bevan give the following as the percentage of cellulose in air-dry esparto: Spanish, 58.0%; Tripoli, 46.3%; Arzew, 52.0%; Oran, 45.6%.

87. Steps of the Process.—The process of reducing it to fiber is a simple one, involving four operations, viz: (1) Dusting; (2) boiling; (3) washing, pulping, and bleaching; (4) screening and making into laps.   The equipment employed for these operations is: For (1), a willow or duster; for (2), an esparto boiler, specially constructed for the purpose; for (3), an ordinary half-stuff or a breaking-in engine of the Hollander type, provided with a drum washer; and, finally, for (4), screening equipment and presse pâte machine, for running off the bleached pulp into a thick sheet.   In place of the Hollander, a pulping machine of cylindrical type is sometimes used; and, obviously, the fiber may be screened before or after bleaching.
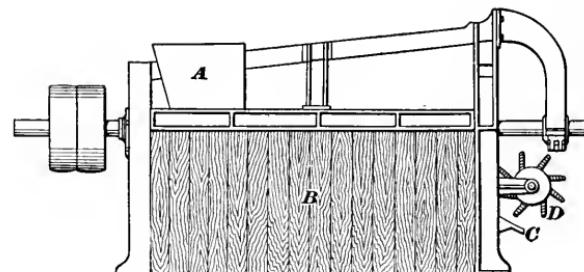
Fig. 16.

88. Dusting.—As the bales of esparto are brought into the mill, they are opened, and the grass is loosened and fed into the hopper A, Fig. 16, of the conical duster or willow.   A conical screen revolves in a housing B, the sand and dust fall through, and the clean grass is discharged at the spout C onto a conveyor, which takes it to the loft over the esparto boilers.   The paddle D keeps the spout clear.   In the early days it was deemed necessary to remove all roots by hand picking, girls being stationed alongside the belt conveyor for this purpose; but as care is now taken to avoid pulling the roots while harvesting the grass, this precaution is considered unnecessary.   The root ends of the grass are hard, and those that remain partly untouched by the caustic liquor during the cooking are removed by the screens. The loss in weight during the dusting varies from 1 % to 6 %; and the grass, after dusting, contains from 2 % to 3.5 % of mineral matter, the bulk of which consists of silica, which is soluble in sodium hydrate, and comes away in the black liquor as silicate of soda.

COOKING

89. Types of Digesters.—A form of digester in which the boiling takes place is shown in Fig. 17.   It consists of an upright cylinder M with domed top, and fitted internally with a per-forated false bottom B, from the center of which, a vomit pipe C receives the liquor that drains through and carries it upward, to pass again through the body of the grass.   A steam jet I in the
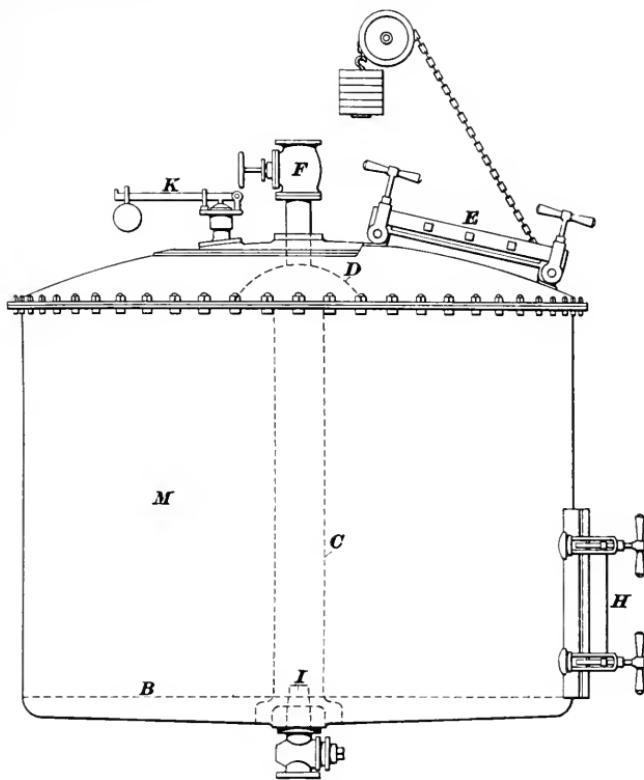

FIG. 17.

bottom of this vomit pipe, pointing upward, throws the caustic liquor against a dash plate D at the top, which distributes the lye over the surface of the grass.   The boiler is also provided on its side with a circular door H immediately above the false bottom, to enable the workman to remove the cooked fiber, and with another door E, on the top crown, for the introduction of the grass. K is a safety valve, and F is a fitting for introducing cooking liquor and wash water, if desired.   Liquor may also be run in through the charging hole.

90. A digester of a newer type, shown in Fig. 18, resembles the foregoing in its action.   Two internal circulating, or vomit, pipes *A* are provided, one on each side of the vessel; these throw the liquor into the upper chambers *B* under the crown, and the liquor is then distributed over the surface of the grass, as shown in the illustration. Letters correspond to parts described for Fig. 17. Obviously, in place of the vomit pipes, a centrifugal pump may be used for circulating the liquor; and the boiler and its contents may be heated with a coil, instead of by injecting steam directly into the charge, in a manner similar to that sometimes employed in cooking wood pulp.   These esparto boilers are built to hold from $2\frac{1}{2}$ to 3 tons of grass per charge.

91. Cooking Liquor.—The stem of esparto (and of grasses in general) is largely cuto-cellulose or pecto-cellulose, instead of ligno-cellulose as in jute.   This must be broken up by hydrolysis, and the non-cellulose substances, fats and waxes, rendered soluble. Some are changed to acids, which unite with the soda; others form sugars and other soluble substances.

The resolving fluid used is caustic soda (sodium hydrate),

Fig. 18.

although the so-called sulphate processes, in which a mixture of sodium hydrate and sodium sulphide is used, is equally applicable.   The caustic liquor is obtained by causticizing 58% soda ash with lime in the usual way (see the Section on *Soda Pulp*,
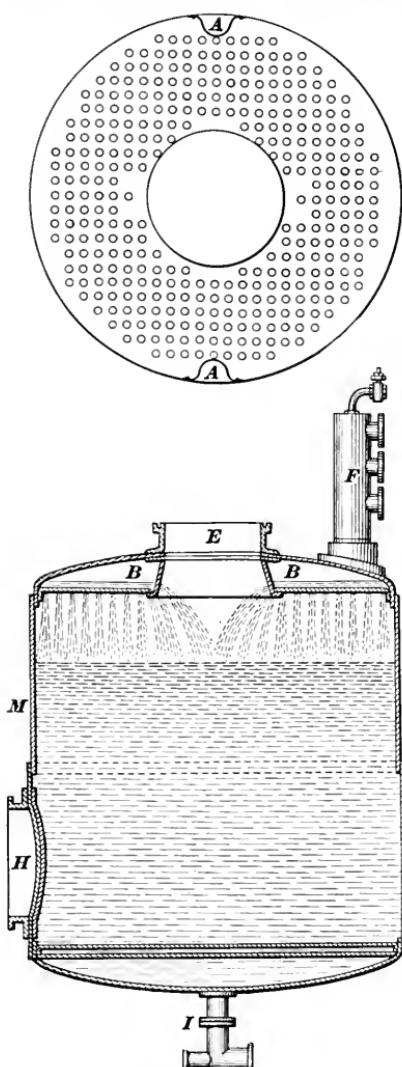
Vol. III), and the amount of alkali used varies with the quality and kind of grass and the treatment. For the finest quality of esparto, from 18 to 19 pounds of 58% alkali per 100 pounds of grass are enough; but for the coarsest immature kinds, as much as 25 pounds are required. These quantities of alkali, however, depend to a certain extent on the steam pressure (or temperature) and the time adopted for cooking. When high temperatures (or pressures) are used, less alkali is needed. The volume of lye used varies within somewhat narrow limits, and would depend on the quality of the steam and whether or not the charge is heated directly, with injected steam, or indirectly by means of a heating coil. As a general rule, it approximates to 95 cubic feet per 2000 pounds of grass in the former case; and, in the case of Spanish esparto, using 18 pounds of alkali per 100 pounds of grass, it would correspond to a liquor having a specific gravity of 1.048, at 62°F. (9.6° Twaddell), and would contain total alkali equivalent to 60 grams of soda per liter, of which 92% to 94% exists as hydrate, the other 8% to 6% being carbonate. When 25 pounds of 58% alkali are used, the liquor would have a specific gravity of approximately 1.066, at 62°F. (13.2° Tw.); it would contain soda equivalent to 84 grams per liter, of which from 92% to 94% exists as hydrate. The time required for cooking also varies, and depends on the amount of soda and the steam pressure or temperature; from 50 to 60 pounds pressure is common in modern esparto mills. At this pressure the average cooking time occupies from 2 to 3 hours.

92. Cooking Operation.—The following is a representative example of a cook in actual practice, in which fine, well matured esparto was treated, the amount of alkali required being 18 pounds (58% alkali) per 100 pounds of grass.

Esparto (Oran, fine ripe grass)...........	6000.0 lb.
Caustic liquor, volume.................	285.0 cu. ft.
Caustic liquor, Sp. Gr. (10°Tw.).........	1.050
Caustic liquor, grams 58% alkali.........	60.0 per liter
Caustic liquor, grams soda (Na_2O).......	34.8 per liter
Caustic liquor, per cent causticization.....	92.0 per cent
Time of boiling.......................	$2\frac{1}{2}$ hours
Temperature.........................	298°F.
Pressure (gauge)......................	50 lb.

93. To carry out this cooking operation in practice, the boiler is first of all filled with the loose grass, care being taken to

distribute it uniformly inside. The liquor is then run in, and the vomiting is begun. The caustic lye soon softens the esparto, causing it to fall and to pack somewhat closely on the perforated false bottom. As this takes place, more grass is added until the whole charge of 6000 pounds has been introduced. The main lid is then securely bolted down and the heating (and vomiting) is continued until the pressure reaches 50 pounds. During the heating, a little steam is allowed to escape, by means of a small valve provided for the purpose, to carry away the air and light oils inside. The pressure is maintained for $2\frac{1}{4}$ or $2\frac{1}{2}$ hours, after which it is blown down, the escaping steam being used for heating the next charge of caustic liquor, and, also the weak liquor for the first and second washings. When the pressure is nil, the black liquor is drained off, the hot washings from a previous operation are pumped in, and the vomiting is again begun. This strong wash liquor is run direct to the soda-recovery house and is mixed with the strong black lye. The recovery of the alkali in black liquors is fully treated in Vol. III, Sections 5 and 6. Hot water is now added, and the grass is washed a second time, the weak liquor from this washing being run off into a tank, to be used again as a first washing for the cook. The top manhole lid is now removed, and, if necessary, further wash water is added; but, as this will contain but a small quantity of soda, it may be run to waste. After draining thoroughly, the side door is opened, and the boiled grass is removed by hand into galvanized iron or wooden box trucks, or is otherwise conveyed, to the Hollander or bleaching engine. When properly boiled, the strands of grass will easily come apart, or will be broken up into pulp; in appearance, the original color of the grass will be preserved, but will be brightened.

WASHING AND BLEACHING

94. Operation.—Final washing and bleaching are usually carried out in one operation, in a Hollander of large capacity, fitted with drum washers, in order to remove the last traces of soda and some intercellular matter, which invariably passes away with the wash water. The bleach liquor, consisting of a solution of calcium hypochlorite $Ca(OCl)_2$, of a Sp. Gr. of 1.040 (or 8°Tw.) is then run in. In most cases the temperature is also raised to about 100°F., either by washing with hot water or

by direct heating with injected steam prior to bleaching. In this way, the bleaching is hastened. The fiber, after the addition of the bleach liquor, quickly changes color, if well-matured grass is being treated; but the color changes more slowly if the grass is green, always assuming that no great excess of bleach has been added. The pulp is kept in circulation for some hours; it is then dumped into a pulp chest, whence it is pumped to the screens A, which are usually placed at the end of the presse-pâte machine, Fig. 19. The screened stock passes to the flow box B, which delivers it in a quiet, shallow stream, over the apron C to the Fourdrinier wire D. Rubber deckle straps E prevent escape over the edges. Water drains through the wire, some is extracted by the suction boxes F, and some by the couch press (rolls) G and H. The sheet then passes to the felt K, which carries it through the press rolls L and M and delivers it at N, to carts or a conveyor. The fiber is run off on this machine as a thick web, and it is taken to storage or to the beating engines for conversion into paper. As a general rule, the fiber is bleached before screening, as this is considered a simpler method than that of screening before bleaching.

Consideration should here be given also to the wet machine, see Art. **59.**

95. Yield Depends on Quality.—The yield of air-dry fiber containing 10% moisture, from 100 parts of grass, depends very largely upon the quality of the esparto. From well-matured Spanish and Oran, it does not exceed 45%, while in the case of the unripe or green kind it may be as low as 40 % or even under. Not more than 42% may be expected, on an average, from deliveries of North African grass.

Fig. 19.

**96. The Sulphate Process.**—Esparto fiber may also be prepared by the sulphate process, with equally good results.
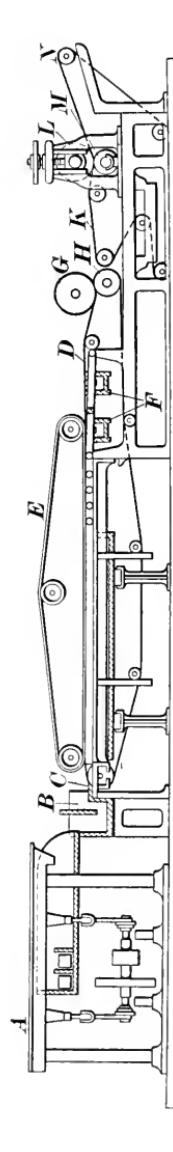
The manufacturing conditions being very similar to the fore-going, as outlined for caustic soda.   For details see Section 6, Vol. III, *Manufacture of Sulphate Pulp*.   The advantages claimed for the sulphate method are: (1) A greater yield of bleached fiber; (2) a greater preservation of its strength.   The treatment as a whole is also cheaper, salt cake being used in place of soda ash.

STRAW PULP

97. Kinds of Straw Pulp.—There are two kinds of straw pulp manufactured, viz.: (1) **Yellow pulp,** used for the production of cheap wrapping papers and straw board; (2) **straw cellulose,** invariably put on the market in the bleached state, which is used for making the finest writing papers.

Note.—Straw.   In straw pulp, the bast cells or fibers form the greater part of the pulp.   These are comparatively short and slender, with sharp pointed ends; at quite regular intervals the walls appear to be thickened and drawn together to resemble joints.   The dimensions of straw fibers vary with the kind of straw and with the conditions of growth, nature of soil, etc. They are longer than those from esparto, but not so long as the fibers from spruce wood, and would compare more nearly with poplar fiber in paper-making value.   Accompanying the bast fibers in straw pulp are numerous epidermal cells from the pithy portion of the stem.   (See Fig. 1, Section 1, Vol. III.)   The latter vary in shape from nearly round to long, oval cells, whose length is several times their width.   Both types of cell aid materially in the identification of straw pulp.

Straw as used in paper making includes the stems and leaves of the various cereals.   The composition of straws, particularly with regard to the amount of ash and its constituents, varies greatly with the soil upon which they were grown.   Wolff gives the following analyses for different straws:

	Winter rye, %	Winter wheat, %	Summer barley, %	Winter barley, %	Oats, %	Corn, %
Water................	14.3	14.2	14.3	14.3	14.3	14.0
Ash..................	3.2	5.5	7.0	5.5	5.5	4.0
Fat and wax..........	1.3	1.5	1.4	1.4	1.4	1.1
Nitrogenous matter.....	1.5	2.0	3.0	2.0	2.5	3.0
Starch, sugar, gums, etc.	25.7	28.7	31.3	28.4	36.2	37.9
Cellulose..............	54.0	48.0	43.0	48.4	40.0	40.0

See also Lloyd, "The Structure of Cereal Straws," *Pulp and Paper Magazine of Canada*, Vol. xix, pages 953-4, 973-6, 1002-4, 1025-6, 1048-50, 1071-5 (1921).

98. Yellow Straw Pulp.—Yellow straw pulp is manufactured by boiling the straw under pressure in milk of lime, to which a small quantity of soda may be added; and, afterwards, passing it through kollergangs and beaters, before finally converting it into paper or board. The straw is cut into chaff of about 1 to 1½ inches long, thoroughly dusted by passing it through a suitable willow, see Fig. 16, and then digested in rotary boilers, preferably of the spherical type, Fig. 8, at a pressure of 40 to 50 pounds above atmosphere, with 10% of its weight of caustic (quick) lime that has been made into a milk with water and then carefully strained, to free it from grit. The volume of liquid used should be sufficient to cover the chaff, and the boiling should be continued until the particular kind of straw under treatment is softened sufficiently to be broken up or pulped in the disintegrator. When the boiling is finished, the straw is washed, and is then ground up into pulp in the kollergang or beater. A yield of 100 parts of yellow straw pulp requires 133 parts of straw, (yield 75%), 13.3 parts of caustic lime, and 20 parts of coal (for boiling only). The power required to drive the cutters, digesters, kollergangs, beaters, and pumps is approximately 25 h.p. per 2000 pounds per day. The product is coarse in appearance and low in strength.

99. Straw Cellulose.—The routine of making this product is very similar to that for esparto. The straw should be as free from weeds as possible, cut into chaff, then dusted (to get rid of sand, etc.) and, finally, boiled in a caustic-soda solution. In recent years, the sulphate process (see Vol. III, Section 6) has been used with much success, as it yields a cheaper boiling fluid, a higher yield of cellulose, and a stronger fiber, without altering the mode or routine of manufacture to any great extent.

100. Kinds of Straws Used.—The straws usually employed are wheat, rye, oat, and barley, though flax straw from plant grown for linseed, being unsuited for textiles, is being developed as a source of paper-making material. The fiber has the characteristics of linen; but it requires a drastic preliminary treatment, as does straw. It can be bleached to produce a white paper of good color and strength. Wheat and rye yield cellulose fibers that are closely allied in point of length and strength or felting properties; oat, on the other hand, has length, but is of medium felting power; while barley straw is short, soft, and of low felting power.

All these fibers are hard and crisp when bleached and dried, and they impart this property to the paper of which they form a part.

101. Preliminary Treatment.—As a general rule, when these four varieties are available, a mixture of all four is used. It is essential that they be free from weeds, since it is quite impossible to make high-grade, bleached-straw cellulose suitable for high-grade writings when weeds are present to any great extent. In the best factories, the straw is opened out, or is spread by hand onto a wide traveling canvas belt, which leads to the chaff cutter, alongside of which, girls are stationed, whose duty is to pick out the weeds. The straw is then delivered to the cutter, which cuts it into chaff from 1 to $1\frac{1}{2}$ inches long. From this, it falls into the willow or duster, and is then blown through a galvanized iron pipe, into the loft over the digesters. Sometimes it is given a preliminary dusting before it enters the chaff cutter, every care being exercised to get the chaff as clean as possible.

102. Cooking Liquor.—The cut straw is then digested in rotary digesters, either with caustic soda or with a mixture of hydrate and sulphide of soda, as in the sulphate system of manufacture. The following figures represent the proportion of lye to straw when cooking with caustic soda alone, and, also, other conditions of the boiling process, all from actual practice, as followed in a Dutch factory:

Weight of straw (mixture of oat and wheat)	=	4480 lb. per boil
Amount of caustic lye	=	1610 gal. (Imperial)
Time under steam pressure	=	4 hours
Steam pressure (gauge)	=	60 lb. per sq. in.
Maximum temperature	=	307°F.

The composition of the above lye was as follows: Sp. Gr. 1.0525 = 10.5°Tw.; total soda Na_2O = 32.49 grams (= 53.78 grams sodium carbonate) per liter, of which about 82% existed as hydrate (*i.e.* caustic soda), 9.3% as carbonate, and 8.3% as silicate, with traces only of sulphide. The silicate of soda is formed from the silica, which exists in very appreciable quantities in all cereal straws. As the whole of this silica is soluble, it affects the consumption of the recovered soda liquors and the loss of soda to a very large extent, since silicate of soda is quite useless for the cooking operation, and must be replaced by fresh soda ash in the recovery process.

103. Cooking Process.—The digesters, as previously stated, are almost invariably of the rotary type, either horizontal or

vertical cylinders, Fig. 7, or spheres. The latter revolve on trunnions, and are provided with suitable manholes and covers for filling and emptying; also, with arrangements at the trunnions for heating the digester and its contents with steam. Sometimes baffle plates are fixed inside, to promote the mixing of the charge; since the straw softens, and is apt to mat together into a mass, which slips as the digester rotates. Several times during the boiling, the revolving is stopped for a few minutes, and the air inside the digester is allowed to escape through a small relief valve. The most suitable digesters are the spherical type, Fig. 8, or the upright cylinder with coned ends (see Fig. 4, Section 6, Vol. III), driven by worm gearing, and having a capacity of from 3 to 4 tons of straw. The charge of pulp and black liquor may be dumped or blown under pressure from these digesters into the wash tanks with greater care than from those of the horizontal cylindrical type. The digester space required varies from 120 to 150 cubic feet per ton of bleached-straw cellulose made per week. That is to say, 50 tons of fiber per week would require, on an average, about 6750 cubic feet of digester capacity.

104. Washing and Bleaching.—The contents of the digester are emptied or blown into the washing tanks, where the fiber is washed by displacement. These tanks can be arranged according to Shank's system, as applied to the lixiviation of ball soda in the Le Blanc alkali process, in which the wash liquor (or water) flows from one to the other by gravitation (see Fig. 19, Section 5, Vol. III). Or, instead of this, the washings may be pumped from one to the other, the weak washing liquor being distributed over the surface of the fiber in the receiving tank by a rotating spray pipe, as in the washing system arranged for soda pulp. In all cases, since the fiber is fine and settles down on the filtering medium in a somewhat compact mass, the displacement of the stronger lye by the weaker wash liquors (or water) goes on slowly, and reasonable time must be allowed for washing. For the same reason, an unusual amount of draining or filtering surface should be provided, about 35 square feet per ton of pulp per day. The washing of the fiber should be conducted with the greatest care, to avoid undue dilution of the black liquors going to the recovery house; for this reason, it should not be hurried.

The washed fiber is then forked onto a travelling belt that is placed over these tanks, and which conveys it to a pulp opener or *rafineur*, to completely disintegrate it; or it is washed out with a

hose, through a valve or door into a pulp chest that is fitted with an agitator, and from there is pumped to the opener. The object of the opener is simply to break up the bundles of fibers. After this, it passes to the bleaching engines—Hollander or Bellmer type (Vol. III, Section 9, *Bleaching of Pulp*), where it is given a final washing by a drum washer, Fig. 11, covered with fine-wire gauze (60 meshes to the linear inch), with pure, clean water prior to the addition of the calcium hypochlorite or bleaching powder. As in the case of esparto, the temperature is raised to 100°F. and the pulp is allowed to circulate until it reaches the desired color. Finally, the fiber is run off on a presse-pâte machine, Fig. 19, into a thick web, or is passed over a Fourdrinier drying machine.

These different operations must be carried out with care and intelligence, to avoid contamination with dirt; otherwise, the straw cellulose will not be suitable for the production of the highest-class writing papers, etc.

105. Yields.—The amount of cellulose shown by chemical analysis of these straws, is never obtained in actual manufacturing practice, because a part of the fiber is lost during its manipulation in the factory, and a portion is dissolved by the caustic liquor. The percentage found by analysis even differs for the same kind of straw from different districts. The whole question of yield is therefore a complicated one. Barley straw yields much less than oat, wheat, or rye. But when these three are used in about equal proportions, 100 lb. of dry straw (8% to 10% moisture) will produce from 40 to 41 lb. of bleached air-dry pulp containing 10% moisture. The proportion of caustic soda used per unit weight of straw in the cooking has a great influence on the yield and the bleaching properties of the fiber, as exemplified by the following table, compiled from actual practice by Roth:

Situation of works	1000 Kilos of straw required			1000 Kilos of straw yielded in fiber	100 Parts of air-dry pulp required		
	Soda ash	Lime,	Bleach		Soda ash	Lime	Bleach
	Kilos	Kilos	Kilos	Kilos	%	%	%
South Germany	225	160	105	450	50.0	35.5	23.3
Austria............	225	160	72	400	56.25	40.0	18.0
Saxony............	240	150	85	435	55.1	34.4	19.5
Bohemia..........	200	160	175	500	40.0	32.0	35.0

A study of this table reveals the fact that the yield of fiber is varied indirectly with the amount of caustic alkali used. That is to say, the greater the amount of caustic alkali used, the less the yield of fiber. Also, that the bleaching powder required increases with the yield. These facts, it may be stated, are common to all fibers prepared by the soda method, and they have been confirmed by many investigators, after careful experiment.

QUESTIONS

(1) (a) Where does manila fiber come from? (b) how is it treated?

(2) Why is jute limited to the manufacture of coarse papers?

(3) Describe an esparto boiler.

(4) What are the several kinds of pulp straw, and the use of each?

(5) How is straw cooked for a yield of 75%?

106. Bamboo.—The enormous quantity of bamboo in the world, and its very rapid growth, makes this peculiar grass a promising source of paper-making material. The need for its exploitation is in sight; years of research by Raitt and others have shown the feasibility of preparing bamboo pulp by the soda or the sulphate process. Indian bamboo contains 50% to 54% cellulose, and Philippine bamboo contains slightly more. Raitt found the soda process to yield 41% to 43% of bleached pulp suitable for high-grade papers. The sulphate process gives about 1% higher yield, with considerably less bleach—15.5% to 18%. The sulphite process is unsuited, because of the amount of silica in the plant and the difficulty in maintaining a strong bisulphite liquor in the tropics. See *Indian Forest Records*, Vol. 3, Part 3.

Raitt recommends that (1) only shoots be cut that have attained the full season's growth; (2) that the culms be seasoned at least 3 months before use; (3) that it be crushed; (4) that the starchy matters be extracted; and (5) that the sulphate process be used.

Satisfactory digestion of the five species investigated was found to be possible with 20% to 22% caustic (hydrate and sulphide), temperature 162° to 177°C., pressure 80 to 120 lb. per sq. in., and 5 to 6 hour's cooking time.

NOTE.—**Bamboo.** Bamboo fibers closely resemble those from the straws in many of their characteristics. According to Raitt, the average length of the ultimate fibers is from 2.20 to 2.60 mm. according to the variety, and diameters are from 0.018 to 0.027 mm. While not so long as spruce fibers, they are much longer than those from any of the deciduous trees.

PREPARATION OF RAG AND OTHER FIBERS

EXAMINATION QUESTIONS

(1) When and where were rags first used for making paper?

(2) What kinds of rags are used for (*a*) writing paper? (*b*) wrapping paper? (*c*) roofing paper?

(3) In purchasing rags, what materials would you limit or exclude?

(4) Describe the rag thrasher, and tell what it does.

(5) Why and how are rags sorted?

(6) Describe the apparatus and the process of cutting rags.

(7) What is accomplished in the cooking of rags?

(8) Describe one type of rag boiler.

(9) Explain the filling of the boiler and the cooking and emptying.

(10) Name the variable factors in cooking, and state how a change in each one affects the others.

(11) (*a*) Explain what happens to the rags while washing; (*b*) how long does this take, and how much water is used?

(12) Why are rags bleached?

(13) How is the bleach liquor prepared for bleaching rags?

(14) Express your opinion of a foreman who used 12% of bleach for Thirds and Blues and added a chemical to neutralize the excess.

(15) (*a*) What are the items of loss in preparing rags? (*b*) how do these vary with different classes of rags?

(16) What kinds of paper are made from manila hemp?

(17) How does jute differ from other fibers considered in this Section?

(18) What is the prospect of using cotton-seed hull fiber or linters in paper making?

(19) What is the source of esparto, and for what papers is it used?

(20) (*a*) How is straw cellulose prepared? (*b*) what is the average yield?

TREATMENT OF WASTE PAPERS

By Ed. T. A. Coughlin, B. S., Ch. E.

USE, VALUE, RECOVERY AND GRADING

USE AND VALUE OF WASTE PAPERS

1. Reasons for Extensive Use of Waste Papers.—The use of printed waste paper, or *old paper stock*, as it is commonly called in the mill, has developed to such an extent on this continent that it rivals, even surpasses in some cases, the use of soda and sulphite pulps in certain grades of paper. There are many reasons why old paper stock has reached this point of importance, some of which are: the immense available supply of material; the low cost of material; low cost of converting into paper pulp; desirability of the converted product.

2. At the present time, old paper stock is employed in the manufacture of container board, box board, wall board, leather board, papier-mâché, roofing paper, manilas, carpet paper, wrapping paper, bag paper and printing papers. In the finer grades of paper, such as book and printing paper, body stock of coated paper, lithograph and book papers, the cheaper grades of writing, mimeograph, offset, drawing, bible, blotting, map, parchment, music, catalog, tissue, water leaf and cover papers, the percentage of old paper stock used in them ranges from 10% to 80% of the furnish.

3. It would be difficult to ascertain the limits of the field for consumption of old paper stock. This material, when properly de-fibered and freed from colors, dirt and ink, can be safely used in all but the finest grades of writing and record papers, and in papers that call for a specially long fiber, where the

§2 1

composition of the sheet to be made has been specified previously. Consequently, it is not strange that what formerly was a waste and a useless commodity now finds a ready application to almost every grade of paper made.

By far the largest tonnage of this waste-paper material is re-made into boards, liners and newsprint; in fact, it has been estimated that about 10,000 tons of old paper stock is daily re-made into the classes of paper here mentioned, and about 2500 tons is employed daily in the manufacture of book, writing and the other grades of the better class previously referred to. This Section will deal more particularly with this latter application of the great American waste.

As a subject for discussion, "The Reclamation of Printed Waste Paper" has been almost as popular a theme as "A New Substitute for Wood Pulp." For years, it has been the goal of many determined paper makers, of many enterprising business men, also of many adventurous fakers, to work over old magazines, books, letters and bill heads, and even old newspapers, in such a manner as to produce a grade of paper equal in every respect to the original. Many machines have been devised, and many processes have been worked out in secret, to re-pulp and de-ink discarded paper, but a large proportion has resulted in economic failures. Notwithstanding quite extensive skepticism concerning the practicability of the process, thousands of tons of paper are daily being re-made into high-class book and printing papers and similar grades, which compete with, and sometimes quite materially undersell, the pure-fiber papers.

4. Value of Waste Paper.—A more general appreciation of the market value of rags, rope, and waste paper of all kinds, would increase largely the supply of old paper stock; it would also add considerably to the income of the general public. According to figures for 1919 by the U. S. Department of Census, rags to the value of $23,000,000 were used in that year for paper making, besides $7,000,000 of rope, jute bagging, waste, threads, etc., while several times this amount could be secured under proper collecting conditions. Waste paper to the value of $43,000,000 was used in 1919 in paper making, and it is estimated that three times this amount could be made available. Even though 1919 was a period of high prices, it is therefore evident that the value of the waste paper annually destroyed is very great; if reclaimed and used, it would serve a double purpose—the production of

good paper, and the conservation of the material, largely wood, that the waste paper replaces. The 1,000,000 tons of paper now wasted each year, and which could be saved, would make all the building, bagging, cover, blotting and miscellaneous papers, and all the paper board, that is now produced.

Considering, then, the immensity of the field and the profits to be derived, it is only logical that many methods should have been devised and patented for reclaiming old paper stock.

METHODS OF RECOVERY

5. Classification of Methods.—It would be almost an impossibility to collect and record all the different methods that have been patented. Those processes that are in practical use in the mills will be considered in detail. The methods are here treated under three heads: mechanical action alone, without the use of chemicals; chemical action alone; combined mechanical and chemical action. For each class, many processes, and the equipment therefor, have been patented. Some of these show a lack of knowledge or experience regarding their practical, economical operation. It may be remarked that few branches of the paper industry have brought out more patents than this.

6. Mechanical Processes.—Very few methods of any value are to be found in the class that includes the processes grouped under mechanical action alone; for, to produce a good white pulp for book paper, it is necessary that the inks be entirely removed. Printing inks consist mainly of some pigment, which is combined with an oil or varnish body, called the *vehicle*. To remove the ink, saponification by an alkali of some kind is necessary, in order to effect a combination of the alkali with the vehicle and free the pigment. However, under mechanical action alone may be classed all methods employed in roofing and board mills that use only old newspapers, wrapping papers, and box boards. For the grade of paper there produced, the color is of secondary importance, and the products are usually heavily colored with loading ochers and red oxides.

7. Chemical Processes.—Treatment of papers by chemical action alone is understood to refer to those processes in which the papers remain stationary, the liquor used being allowed to circulate and permeate the mass thoroughly. In this way, the

ink is broken up, being deprived of its vehicle, and it is easily washed out subsequently in the washing engines. This method is the practical outcome of the earliest experiments in treating waste papers; it is called the *open-tank cooking process*, and it is still largely in vogue in mills of the Middle West.

8. The first description of a process of this type is credited to J. T. Ryan, of Ohio, and was patented by him. After being dusted, the papers are cooked with a soda-ash solution of 5°Be. at 160°F.

In the method patented by Horace M. Bell and Edmund R. Lape, of Swanton, Vt., the dusted papers are agitated in a solution of 1 part soap and 600 parts water for each 10 parts of papers; the loosened ink is then washed away.

9. Combined Mechanical and Chemical Processes.—By far the greatest number of actual and proposed methods depend on the combined chemical and mechanical treatment of the papers; the most important of these is the rotary-boiler process, the details of which will be thoroughly discussed later. The cooking-engine process, and several other patented processes will also be considered in detail.

10. John M. Burby states, in U. S. patent No. 1,112,887, that alkalis are most suitable for use as solvents in processes for the recovery of pulp from printed waste papers; but, if they are used in solutions containing more than the equivalent of 2 parts of caustic soda to 1000 parts of water, or if weaker solutions are employed at a temperature of 150°F. or higher, they produce a discoloring effect on the mechanical wood pulp that may be contained in such waste papers. Mr. Burby found that a solution of 1 part (or even less than 1 part) of caustic soda, measured by weight, in 1000 parts of water, if employed in proportionate quantities, is sufficient in most cases to counteract the adhesiveness of the oily medium of printer's ink. Other alkalis may be used in place of caustic soda.

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CLASSIFICATION OF WASTE PAPERS

11. Grades of Papers.—Until recently, no definite standards or distinct classes were deemed to be necessary in the classification of waste papers. Perhaps the first distinctions made were: (*a*) Waste papers for No. 1 stock, such as shavings and cuttings

of papers not printed upon and which could be used directly in the beater without preliminary treatment; (*b*) waste papers for book stock, which comprises practically all kinds of printed matter except groundwood, or mechanical, pulp papers; (*c*) all other waste papers, which are made into cheap box board.

12. Quite naturally, paper manufacturers using these wastes, especially book-paper men, noticed that certain grades of paper produced a cleaner and more uniform sheet, and they therefore discriminated in their selection of stock; this has resulted in the following grades of waste papers, with their prices per 100 lb., the latter fluctuating according to the season and to the demand:

Quotations on Waste Paper	Oct., 1915	Oct., 1922
No. 1 hard white shavings	$2.40 –2.50	$4.20–4.40
No. 2 hard white shavings	2.00 –2.10	3.75–4.15
Ledger, solid books	1.75 –1.85	3.00–3.25
No. 1 soft white shavings	1.75 –1.80	3.75–3.90
Ledger stock	1.40 –1.50	2.70–2.80
Magazine, flat	0.80 –0.90	2.45–2.50
Magazine, unstitched, flat	0.95 –1.00	2.65–2.70
Crumpled book stock	0.70 –0.75	2.10–2.15
White blank news	1.05 –1.10	2.00–2.15
New manila envelope cuttings	1.50 –1.60	2.50–2.60
New manilas	1.30 –1.40	2.00–2.10
Manilas, extra	0.90 –1.00	1.80–1.90
Manilas, No. 1	0.65 –0.75	1.50–1.60
Manilas, No. 2	0.35 –0.45	1.40–1.50
Bogus wrappers	0.42$\frac{1}{2}$–0.45	1.10–1.20
No. 1 mixed papers	0.30 –0.35	1.05–1.15
Ordinary mixed papers	0.25 –0.30	0.80–0.90
Over-issues	0.50 –0.55	1.20–1.25
Folded news	0.35 –0.40	1.25–1.35
Box maker's cuttings	0.30 –0.35	1.05–1.15
Telephone books	0.25 –0.30	0.55–0.65

Even with these distinct grades, the mills are continually being annoyed with shipments that do not approach the quality specified in the orders.   If there is to be any profit at all, it is practically impossible for the original packers to grade so closely that the stock can be used without subsequent mill sorting, particularly in the case of magazine, book, and mixed ledger grades. In these items, an allowance of 3% for groundwood is made to the packers; all over this amount is deducted from the original price of the stock, and is paid for as "print."   In magazine stock, an allowance of 3% is made for any book stock that may be

found on sorting; if a greater percentage is found, it is paid for as ordinary book stock. Similar allowances are made in mixed ledger stock, which is very hard to grade.

WASTE-PAPER STANDARDS AND PRICE FLUCTUATION

13. A Satisfactory Standard.—For a long time, there was considerable difference of opinion as to how to grade a paper over which there was a controversy regarding its correct classification. No set standards were in general use among packers until the Theodore Hofeller Company, of Buffalo, N. Y., issued a set of standards, which were found to be satisfactory to all the trade. This classification is as follows:

14. No. 1 Book and Magazine Stock.—No. 1 books and magazines must be free from groundwood paper, parchment paper, magazine covers made of dark-colored paper, school paper, paper shavings, photogravure paper, and free from books with burned edges. The following are some of the books and magazines that will not be accepted as No. 1 books and magazines: Ainslee's, All Story, Blue Book, The Cavalier, Pearson's, Popular, Red Book, Top Notch, Short Stories, catalogues from mail order houses, cheap novels, telephone books, etc. Thick books, approximating the size of Dun's Agency books, should be ripped apart, making each part the thickness of an ordinary magazine.

15. Ledger Stock.—Ledger stock consists of high-class writing paper, account books, ledgers, letters, checks, bonds, insurance policies, legal documents, etc. The paper may be white or tinted, it may be torn into two or three parts, but it must not be torn into small pieces. Covers must be removed from books and ledgers. The following will not be accepted as ledger stock: Postal cards, school papers, telegrams, envelopes, parchment paper, tissue paper, copying books, manila paper, colored paper, railroad bills of lading, freight bills, ledgers or books with burned edges.

16. Mixed Paper Stock.—Mixed paper consists of clean, dry paper from stores, offices, schools, etc. It may include wrapping paper, cardboard boxes, paper book covers, pamphlets, No. 2 book stock, telephone books, crumpled newspapers, envelopes and paper torn into small pieces that is not good enough for book stock or ledger stock. The paper must be free from excelsior, sticks of wood, rubbish, iron, strings, rags, leather or cloth

book covers, free, in fact, from all material that cannot be manufactured into paper.   Bricks, concrete, and even dead cats have been found in waste papers.

17. NEWSPRINT STOCK.—Folded newspapers must be clean, dry, flat, folded newspapers, such as come from private homes, newspaper offices, news stands, libraries, etc.   Pamphlets, mixed papers, and crumpled newspapers, will not be accepted as folded news.

18. Subdivisions of Standard Grades.—In book-paper mills, there is a considerable variety in the grades of paper made; as a consequence, a difference in the quality of old papers used in the furnish is called for.   Most mills have only two grades, which they call No. 1 and No. 2.   The **No. 1 grade** is made up chiefly from ledger stock, for solid ledger books form a very fine sheet. The **No. 2 grade** is made from magazines and books; and, although a good sheet can be made from this stock, it does not, of course, command as good a price as that made from No. 1.   These two grades are sometimes further subdivided by calling the paper made from them **Extra No. 1** or **No. 2,** and **Special No. 1** or **No. 2.**   This difference is created by the use of high-grade ledgers and No. 1 school books, or by a variation in the pulps used.

19. Another Standard Classification.—The following Standard Classification for Waste Paper has been adopted by the National Association of Waste Material Dealers to be effective from July 1, 1922, to July 1, 1923.   Any person wishing to have this circular mailed to them, should forward their request to the Secretary, Times Building, New York.

BALING.   Unless otherwise specified, it is understood that all grades are to be in machine pressed bales.

TARE.   It is understood that unless otherwise specified, tare shall not exceed 3%.

WEIGHTS AND QUANTITIES.   A carload, unless otherwise designated, shall consist of the weight governing the minimum carload weight, at the lowest carload rate of freight, in the territory in which the seller is located.

HARD WHITE ENVELOPE CUTTINGS.   Shall consist of all white, hard-sized (writing) papers, to be free of groundwood, ink and all foreign substances.

HARD WHITE SHAVINGS.   Shall consist of hard-sized, white writing paper, free from colors and tints, groundwood, and other substances.   May contain machine-ruled and unruled paper but not print-ruled.

SOFT WHITE SHAVINGS.   Shall consist of all white book-paper cuttings, free from groundwood, ink, colors, and not to contain over 10% of coated papers.

No. 1 HEAVY BOOKS AND MAGAZINES.   Shall contain all books and magazines, which are to be free of crumpled and scrap papers, and shall not contain to exceed 3% of groundwood, leather, cloth and board covers.

Mixed Books and Magazines. Shall consist of magazines and books, to be free from all other kinds of paper. They must not contain more than 20% groundwood papers, leather, board and cloth covers and foreign substances.

Kraft Papers. Shall contain all kraft papers, free of waterproof papers.

No. 1 Print Manilas. Shall be composed of a majority of manila colored papers, writing papers and office waste. It must be free of soft papers, news and box board cuttings.

Container Manilas. Shall consist of manila and other strong papers, with soft papers such as news and box board papers eliminated.

Newspapers. Shall contain dry, clean newspapers, free from all foreign substances not suitable for the manufacture of paper.

Mixed Papers. Shall consist of all grades of dry waste paper, free from objectionable material or materials that cannot be manufactured into paper.

Note. Variations of the above grades or grades not included in this classification are to be sold by description and sample or by sample.

20. Price Fluctuation.—The fluctuation in the prices of the different grades of waste papers presents an interesting study; it is a direct indicator of conditions among the mills. For instance, the price of No. 1 magazine stock varied from $0.60 to $0.90 in 1911, and from $0.75 to $1.10 in 1907; these figures include the highest and lowest prices in the years 1907 to 1912. These figures are quoted for the years given because the prices in the war years do not represent normal conditions.

Variation in price is due to the law of supply and demand, and is also influenced by the seasons. In the spring and summer months, the collections increase, and the supply on hand with the packers increases to such an extent that storage costs necessitate a quick and ready market; as a result, the price naturally drops. In the fall and winter months, the mills having stocked up to full capacity, the demand for paper stock lessens; but, by reason of the increased cost of collecting, the prices usually increase. However, the price of the higher grades of ledger and shavings is not so flexible; the price of these is governed mainly by the available supply, and by the ruling price of the rags or bleached sulphite that enters into the manufacture of new paper.

QUESTIONS

(1) Compared with the total supply available, what is the probable proportion of waste paper collected?

(2) Under what classification can the processes of treating waste papers be placed?

(3) What is the nature of printing ink, and what chemical action is usually necessary to get rid of it?

(4) Name a class of papers for the manufacture of which, chemical treatment of the waste paper used is not required, and state why.

(5) On what basis are waste papers classified?

SORTING, DUSTING AND SHREDDING

MILL SORTING

21. General Layout of Mill and Sorting Rooms.—The general plan, or layout, of old-paper sorting rooms is practically the same in all mills. The sorting rooms are usually situated in a comparatively isolated part of the mill, to avoid getting dirt in the finished paper; they are generally on the top floor of the mill, so the papers can be delivered by gravity to the cooking
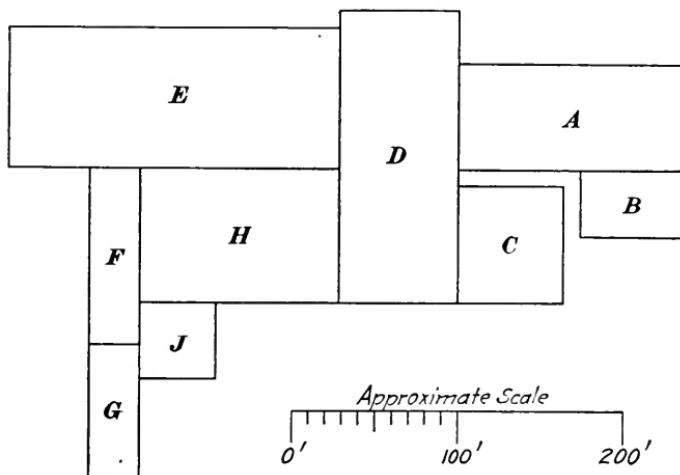
Bldg.	Construction	Purpose
A	4 Stories and basement	Paper storage and sorting
B	4 Stories and basement	Paper storage, cutting and dusting
C	2 Stories and basement	Cooking building
D	1 Story and basement	Beater room
E	1 Story and basement	Machine room
F	1 Story and basement	Finishing room
G	1 Story and basement	Packing and shipping room
H	1 Story and basement	Power plant
J	1 Story and basement	Repair shop

Fig. 1.

or bleacher room. This arrangement causes the various steps to be progressive, in the course of manufacture, and makes the process continuous. A glance at Fig. 1, which is a plan of the mill, will make this clear.

The sorting room must be well lighted and ventilated, since light is essential for close sorting; and the dust-laden air must be continuously removed, to preserve the health of the sorters. A diagram giving the general sequence of the various operations is shown in Fig. 2.
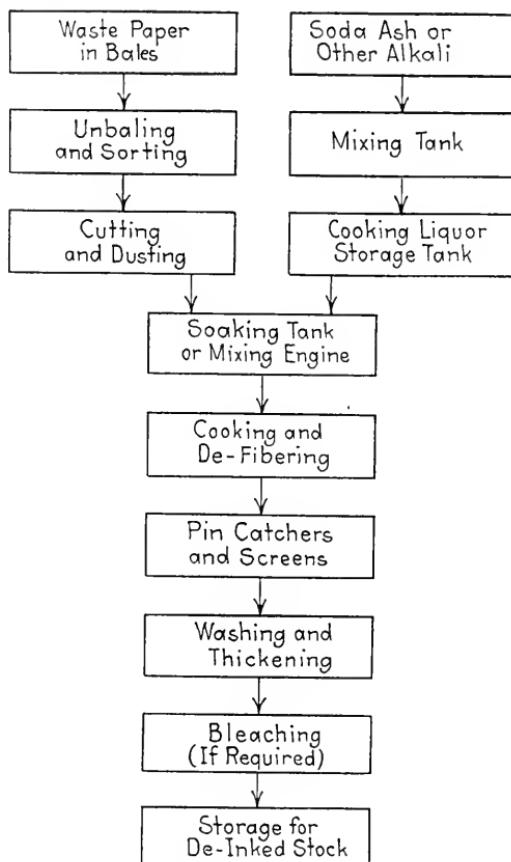
Fig. 2.

BENCH SYSTEM OF SORTING

22. Description of Bench System.—When the waste papers reach the mill, they are weighed in by the storehouse foreman, and the weight is written on a tag, which is securely fastened to the bale. If there is room for it, the stock is placed on a car, sent up on an elevator to the sorting room, and run alongside

the benches, if the sorting room is well supplied with them; after the car has been unloaded, the stock is placed in the storehouse, in numbered bays. The storehouse foreman of a book-paper mill is well qualified to judge the quality of the stock as it comes to him; and if he thinks it will run excessively to print or discards,

A - Foreman's Office
B - Elevator
C - Scales
D }
E } Rest Room
G - Motor
H - Incline Carrier
K - Cutter
L - 6-Cylinder Duster
M - Incline Carrier
N - Shredder
O - 6-Cylinder Duster
P - Fan Duster
R - Horrizontal Carrier
S - Storage for Stock to be Sorted
□ - Sorter's Benches
△ - Sorters
◻ - Bales
○ - Barrels of Sorted Papers
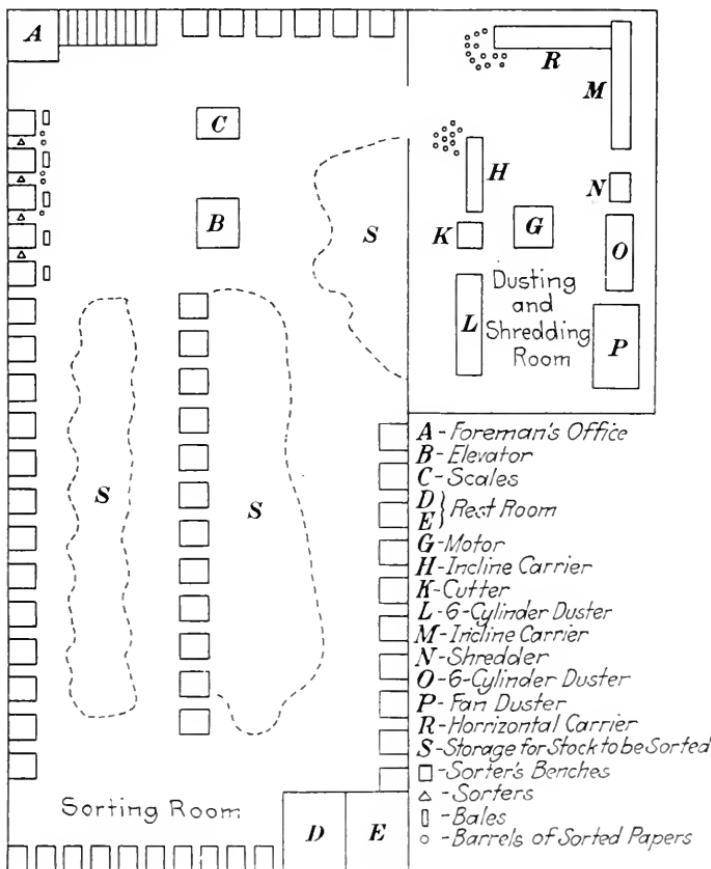
Fig. 3.

making it too costly to sort, he holds up the unloading until he is further advised by the purchasing agent or the sorting-room foreman. This decreases the expense of sorting and increases the efficiency of the sorters.

Fig. 3 represents a layout of the **bench system of sorting** old papers. The sorting benches are arranged along the sides of

practically the entire room; this allows plenty of space in the center for trucking the baled and sorted waste papers.

23. Testing Paper for Mechanical Pulp.—On receiving the bale of papers, the sorter first removes the tag, which she carefully retains; for it represents what the bale weighs, and her pay is based on this weight, a common rate being 15 cents per 100 pounds. Her trained eye tells her at once how any particular bale will sort. She can frequently pick out groundwood (mechanical) pulp sheets, which are termed **print,** by the general appearance of the paper; if the paper is old, the yellowish color indicates at once that it is print. As a further test, she occasionally sprinkles a solution of aniline sulphate over the papers as they lie on the bench, the strength of the solution being $\frac{1}{2}$ pound of ordinary aniline sulphate to 5 gallons of water. If any of the papers turn yellow after being sprinkled, they are at once discarded as print. This test is widely known, and it is extensively used, when the price of aniline sulphate is normal. When using a solution of the strength mentioned, the test is rather slow; consequently, for a more rapid test, a solution composed of equal parts of nitric acid and water is used to identify print. As an indicator, this latter solution acts almost instantaneously, giving a dark brown color to print.

Phloroglucine is also a very satisfactory instantaneous indicator; it is made by dissolving 1 gram of phloroglucinol in 50 c.c. of ethyl (grain) alcohol and 25 c.c. of concentrated hydrochloric acid; the solution should be kept in an amber-colored bottle. This solution imparts instantaneously a deep red coloration to groundwood. Another rapid test, which has quite an extensive use, is prepared by making a strong solution of caustic soda or soda ash; this also gives a yellow or brown coloration to print.

24. The nitric acid test is not always certain, since it will give a brown color reaction to sulphite also. Hence, when aniline sulphate is not to be obtained, and if the nitric acid test is not positive, the sorter must refer to the foreman (or to his assistant, the floorman), whose long experience enables him to judge the paper in question by looking at it or through it, tearing it, or by trying the acid test himself. If there is any doubt at all in his mind, the paper is discarded; for, as previously mentioned, groundwood, or mechanical, pulp will cause trouble later in making a clean sheet of paper.

25. Rate at Which Sorting Is Performed.—When a bale has been opened and the sorting begun, if it appear that close sorting will be required in order to remove all the print and discards, the sorter is required to work by the day. She is thus enabled to earn a fair wage, perhaps $2.65 per day. Otherwise, she would hardly be able to sort more than about 700 to 800 pounds per day, for which she would receive not to exceed $1.25.

The quantity sorted per day, and the consequent cost of sorting, depends directly upon the quality and grade of the papers as received. The grades of waste papers chiefly used in book-paper mills are the following: magazine, book, over-issues, unstitched, lithograph, ledger writing, solid ledger and perhaps some shavings.

Solid magazines are easily sorted. After removing the print magazines, the names of which are well known to the experienced sorter, the deep-color covers of the selected magazines are torn off and placed in a container that receives this kind of discards. Solid school book is also easily sorted, requiring only that the book backs be torn off and the book divided into two or three parts. Over-issues do not require sorting, for they run uniform, and they are fed direct to the duster by the conveyor; this is also the case with lithograph and unstitched papers, provided they are not received in sheets too large for the dusters to handle. Solid ledgers require only that the binding be torn off and the paper separated into suitable thicknesses, about $\frac{1}{2}$ to $\frac{3}{4}$ of an inch. No. 1 hard and soft shavings seldom require sorting. On the above grades, each sorter can handle 2800 to 4000 pounds in 10 hours, depending on her dexterity and speed, and the cost of sorting is at a minimum, or 15 cents per 100 pounds.

However, mills are seldom so fortunate as to receive such fine packings; such lots come only occasionally. The usual run is No. 2 book, magazine and mixed ledger. Although these lots are supposed to have been graded by the packers with due care, all sorts of papers may be found in them. The papers must all be handled separately; and the amount sorted will vary from 1300 to 2500 pounds, averaging, usually, about 2000 pounds per sorter per day of 10 hours.

The mixed-ledger grade causes the greatest difficulty; it is nearly always sorted by the day, and at a rate of about $2.65 per day. In order that a sufficient supply may be on hand when necessity demands an immediate cooking of 30,000 to 40,000 lb.,

5 or 6 sorters are constantly employed on this grade of stock.   It is obvious that this amount could never be sorted at short notice at a normal cost.

26. Loss in Sorting.—The sorters' discards constitute the first shrinkage or loss.   All discards are classified as follows: Print, colors, bagging, carpets, wrappers, tobacco paper, wire and rope. For the period of a year, the amounts and percentages of these discards are shown in the following table:

	Total paper sorted (lb.)	Total discards (lb.)	Total discards (per-cent)	Discards consist of the following:			
				Print	Colors	Backs	Bagging, etc.
Yearly total....	13,273,076	881,423	6.64	4.11%	1.45%	0.25 %	0.83 %
Daily average..	45690	3034	6.64	1874 lb.	665 lb.	114 lb.	381 lb.
Monthly average..........	1,106,089	73,452	6.64	45,367 lb.	16,090 lb.	2772 lb.	9222 lb.

From the above table, which was compiled from daily records, the per cent of total discards is 6.64%; this is the first direct shrinkage in handling old-paper stock, as it is supplied to the general trade.   The table also shows that 4.11% of the discards, or 60% of this shrinkage, is due to print or groundwood. By the use of better graded or better selected stock, such as over-issue magazines of standard quality, this part of the shrinkage can be reduced greatly.

27. Containers for Sorted Papers.—After being carefully sorted, the waste papers are placed in barrels or other suitable containers, which will hold 100 to 150 pounds each.   The containers are placed alongside the benches of the sorters, and, when filled, are trucked away to the conveyor.   The work of trucking, which is performed by men, appears to be quite laborious, ineffi-cient, and an antiquated system; but it possesses some good fea-tures, however.   For instance, each container is numbered with the sorter's bench number; and when the papers are thrown upon the conveyor that carries them to the duster, the two men who attend to this work carefully examine the papers for any discards that may be present.   If the amount thus picked out runs high, the container is returned to the sorter, with the papers that still remain in it, with instructions to sort it over again.

CARRIER SYSTEM OF SORTING

28. Description of Carrier System.—By **carrier system of sort-ing** is meant the process of handling old-paper stock from the bale direct to the carrier or conveyor; this system is illustrated in Fig. 4. Here the outline a b c d e f represents the same rooms as shown in Fig. 3, but with such changes in their arrangement as will adapt them to the carrier, or conveyor, system of sorting paper stock. Note the simplicity of the new arrangement, and gain in floor space, for paper storage.

A = Foreman's Office
B = Elevator
C_1-C_2-C_3 = Carriers
d_1-d_2-d_3 = Test Spray Barrels
D = Rest Room
E = Toilet
M = Motor
ox = Inspectors
o = Sorters
▯ = Bales of Old Paper Stock
F = Shredder or Cutter for Ledger Stock
S = Storage for Stock
T = Storage for Sorted Stock
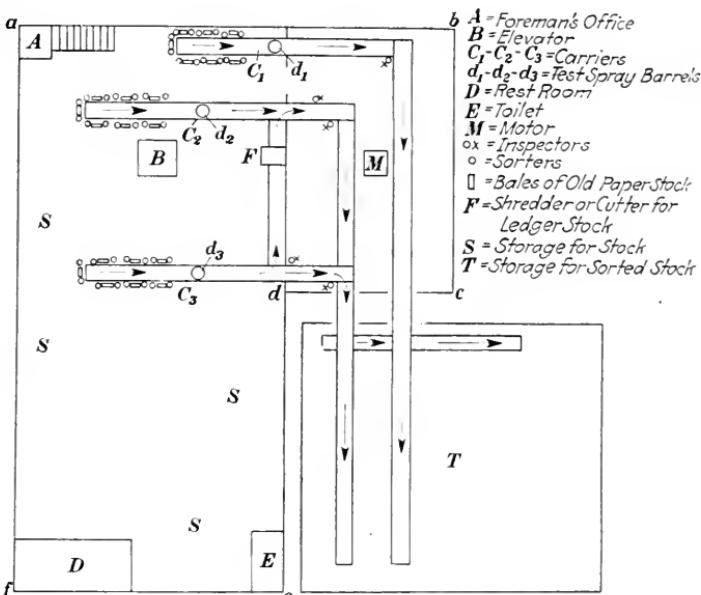
FIG. 4.

The bales of paper stock are arranged on both sides of the carrier C_1, C_2, C_3, which may be made of any suitable length; one having a total length of about 55 feet, and a width of $2\frac{1}{2}$ feet, has been found to be convenient and efficient. Three (3) bales of stock are placed on either side of the conveyor, and one bale at the head (or starting point) of the continuous belt. Two girls (sorters) are stationed at each bale, as shown diagram-matically in Fig. 4; thus 14 girls sort 7 bales directly onto the con-veyor. The discards may be put into baskets or boxes, or they may be thrown into a chute under the carrier. At the mid point of the belts, sprayers d_1, d_2, d_3, are placed; these furnish a con-

tinuous fine spray of a solution of aniline sulphate or other indicator (see Art. **23**) directly upon the surface of the papers, as they pass by on the conveyor. An elevated barrel of solution, connected to a perforated pipe over the conveyor is a good arrangement.

The speed of the conveyor is 55 feet per minute; and when the belt has traveled 20 feet (which takes 22 seconds), the indicator solution will show the presence of groundwood, if any be present in the sorted papers. The use of this spraying test is very necessary, by reason of the prevalence of bleached groundwood in book papers. Since it is impossible to identify bleached groundwood by eye, it is necessary to test every sheet of paper on the carrier. All groundwood book paper is sent to the mill that uses paper of this kind. Two women inspectors are stationed at the delivery end of each carrier; their duty is to throw out any sheet that shows the typical color reaction of the indicator.

It is obvious that the sorters who are grouped around the receiving end of the carrier cannot use up too much time in close sorting; they must keep the surface of the carrier completely covered with papers at all times. They must, therefore, be able to sort by sight, and they must have a good knowledge of the general run of paper stock. Anything that is groundwood, or which appears to be groundwood, or concerning the nature of which there is any doubt in their minds, is at once thrown out as a discard. The discards thus thrown out from the carriers are then closely sorted and tested at the usual sorting benches.

29. Advantages of the Carrier System.—It has been stated that, with the carrier system, 20 girls can turn out 50,000 to 55,000 pounds, gross weight, of paper stock per day of 8 or 9 hours. Taking the lower figure and assuming that each girl receives $2.65 per day, the cost per 100 pounds is $\dfrac{\$2.65 \times 20}{500}$ = \$0.106

= 10.6 cents. This may be compared with 46,000 pounds, gross weight, of paper stock, sorted by 30 girls by the bench system, at a cost of about 15 cents per 100 pounds.

Further advantages of the carrier system are: the decreased wear and tear on the floors; increased storage space, by eliminating the sorting benches; and the elimination of one-man trucking barrels and containers, which are required with the bench system.

DUSTING THE PAPERS

MACHINERY IN DUSTING ROOM

30. Machines Used.—The machinery in the usual dusting room consists of the conveyors, railroad duster, fan duster, and the dust-collecting apparatus. For a capacity of 20 tons in 10 hours, all the necessary power is supplied by a 35-h.p. motor. Drives for each of the above mentioned separate units are taken from a line shaft.

31. The Railroad Duster.—The old method of handling papers consists in emptying the containers, full of papers, onto a conveyor that runs at a moderate speed. Here the papers receive a searching scrutiny for discards, and are then carried on a second conveyor belt, which moves at about twice the speed of the first belt. The second belt carries the papers to the railroad duster, in which the papers are threshed, shredded, and thoroughly separated into individual sheets. The shredding is accomplished by feeding the papers between two rolls having staggered pin teeth. The general details of a railroad duster are shown in Fig. 4, in the Section on *Preparation of Rags and Other Fibers*. A duster of this type, 4 feet in width and having 6 cylinders, has a capacity of 5000 pounds of waste paper per hour.

32. The Fan Duster.—The end of the railroad duster empties into the fan, or cylinder, duster. One type of fan, or cylinder, duster is shown in Fig. 5, Section on *Preparation of Rags and Other Fibers*, in which is a central shaft, with wings, revolving rapidly, and an enclosing screen cylinder, which revolves slowly.

The general action of a fan duster is similar to that of other rotary dusters in use. The papers, which are introduced into the feed aperture of the slowly rotating screen, are rapidly struck, tumbled, and loosened up repeatedly by the fast-revolving beater; this action separates the dust and dirt from the papers, which then fall down through the screen to the bottom of the casing. This occurs while the papers are progressively beaten and tumbled along through the screen, to be discharged in a loose condition.

33. Dusters for waste papers are often made similar to the one just described, but without the central shaft and its wings. In such machines, the papers are moved forward by making the

screen in the shape of a frustum of a right cone. The papers are fed in at the small end and discharged at the other end, usually upon a belt conveyor or into a chute.

34. To render the fan duster with a cylindrical screen capable of operating progressively and to tear the papers apart, beat, dust, and freely discharge them in a loose condition as fast as they are properly fed into the rotary screen, the screen is preferably provided internally with a series of projecting bars. The bars taper, and those at the receiving end are much larger than those at the discharging end; this gives virtually a conical shape internally to the screen. The rotating beater also has pin teeth, and its general outline corresponds to that of the screen, though its diameter is smaller. In operation, the beater may make 30 revolutions to 1 revolution of the screen; this ratio of 30:1 is not fixed, and it may be considerably greater or less. When the screen is about 10 ft. long and 5 ft. in diameter at the large end, and the beater is of corresponding size, a good speed for the screen is 8 to 10 r.p.m. and for the beater 250 to 300 r.p.m. However, good work may be done even though they revolve much faster or slower. The fan duster discharges the dusted papers onto a conveyor belt, and this, in turn, delivers them to the cooking tanks or to storage bins.

35. Power Required.—The power necessary to drive the conveyor belts is estimated to be 1 to 2 h.p.; for the railroad duster, 10 h.p.; for the fan duster, 5 h.p.; and for the exhaust dust fan, about 10 h.p. These figures vary, of course, according to the load on the machines.

36. The Dust.—The exhaust fan is connected to both dusters; it carries off a continuous stream of air that is laden with dust and dirt of all kinds, which is conveyed to a dust collector, where the dirt is removed and the air is purified before being discharged outside. The amount of dust removed varies, of course, with the kind of stock being handled; in any event, it is considered to be an inconsequential item, say 100 to 150 lb. per day in a plant having a capacity of 40,000 lb. of paper.

A sample of the dust was tested. After being ignited, the ash was white in color and was proved to consist of clay or insoluble silicate. As would naturally be expected, volatile organic matter constitutes the greatest part of the dust, which really consists of pure pulp fibers, in the main, and would serve

as an excellent filler in certain papers. An analysis of the dust showed it to contain the following:

	Per Cent
Moisture at 105°C	5.90
Pulp fibers	77.41
Clay	13.13
Alum	2.30
Calcium sulphate	1.25
Total	99.99

PAPER SHREDDERS

37. Methods of Handling Papers for Shredding.—Some mills change the method of handling the sorted papers from that usually followed. In one instance, in its endeavor to have the paper shredded better, the mill discards the use of the railroad duster, and employs a shredder, which reduces the paper to irregular pieces, about 4 to 8 inches square. The shredder has an exhaust fan connected with it, and delivers the papers to a continuous conveyor rake. The rake drags the papers up a short, inclined, coarse-meshed screen, in which much of the finer and heavier dirt is sifted out. The papers then go from the screen to the fan duster, where they are treated as previously mentioned.

TYPES OF SHREDDERS AND CUTTERS

38. A Popular Shredder.—There are a number of good paper shredders on the market, and in use in various mills, which reduce the paper to a size that will quickly absorb cooking solutions. A short description of several of these machines will afford information concerning the principles made use of in their operation.

Fig. 5 shows two views of a popular make of shredder. The rolls Q open up the papers and pass them to the shredding rolls R, which are cleared by pin roll P. The capacity of the machine is 12 tons of book stock in 10 hours. From 6 to 10 h.p. will drive the machine at capacity, and no mechanical skill is required for its operation.

39. An Efficient Type.—Another efficient type of paper shredder is shown in Fig. 6; it is running satisfactorily at
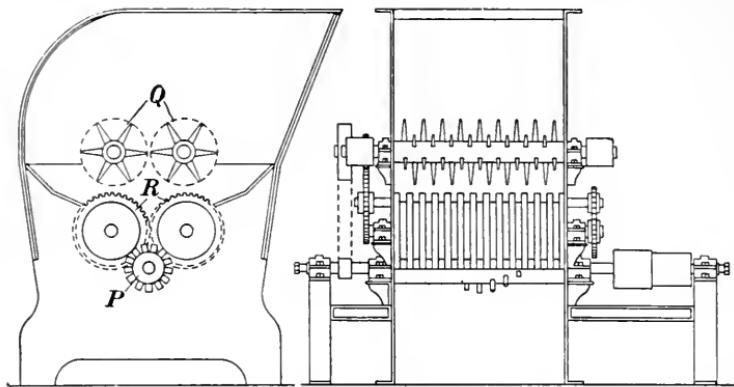
Fig. 5.

several plants in the United States and Canada. The machine is composed of two rolls R, having projecting pins P. One roll runs at a speed of 500 r.p.m. and the other at a slower speed. The flywheel F takes up much of the shock and promotes smooth
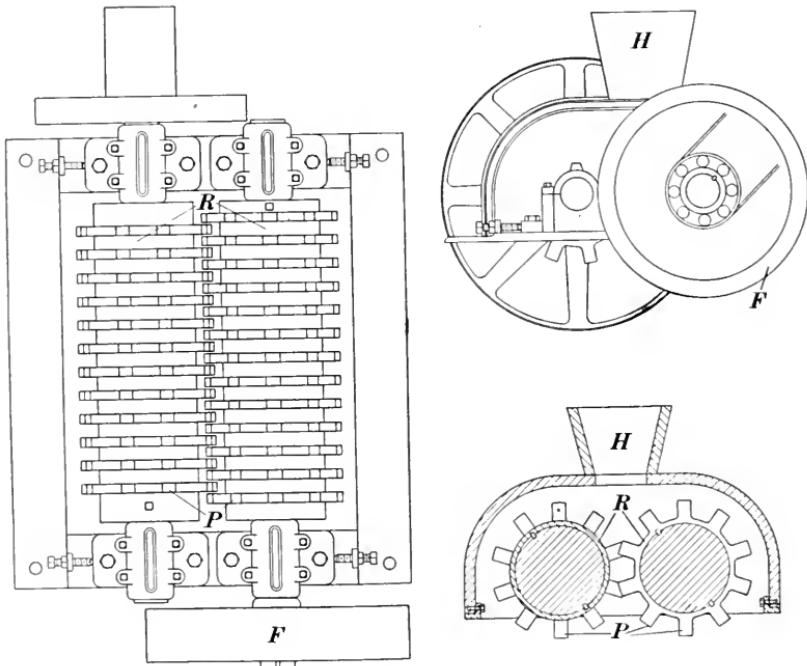
Fig. 6.

running. This shredder takes 6 to 8 h.p. to operate it, and its
capacity is 4000 pounds of book stock per hour.

After coming through the shredder, the pieces will average
about 2 inches square, and they are so well separated that the
cooking solution can percolate through them to the best advan-
tage.   The machine is automatic in its action, and the only atten-
tion it needs is a conveyor to carry the paper to the hopper H,
at the top of the machine, and to another conveyor that removes
the pieces to the bins or cookers.

40. Stock Cutter.—A stock cutter is shown in Fig. 7; it is
installed in many mills for cutting solid ledgers, books and heavy
magazines.   In operation, the waste paper is put into the wooden
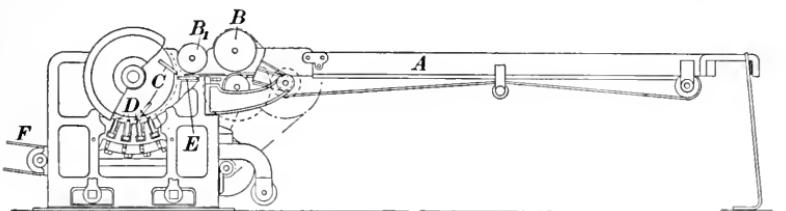
FIG. 7.

apron box A; it is then carried up by the rubber or canvas apron
until it is caught by the large, or breaking-down, feed roll B;
this roll carries the paper forward to the small feed roll B_1, which
carries the paper forward until it is cut by four revolving knives
C, two of which are shown in the illustration, which shear against
the top bed knife E.   The stock is then carried down, and is
cut and re-cut by the four revolving knives against the four
cradle knives D.   The weight of the machine is 8300 pounds; it is
so constructed that the shock and jar that result from the cutting
of thick books is hardly noticeable, giving practically no vibra-
tion.   Its rated capacity is a minimum of $2\frac{1}{2}$ tons per hour; but it
has cut and handled 5 to 6 tons per hour, depending on the
amount of power that can be furnished to it, and the length of
cut desired for papers.   Belt F removes the cut papers.

41. A Well-known Shredder.—Another well-known shredder
is shown in Fig. 8.   Here A is a roll with projecting pins P, to
open the stock, which is fed through the hopper H.   The shred-
ding is completed by blades or bars B on roll R, and the paper is
delivered at T.   This shredder takes from 5 to 15 h.p., depending
on the size of the magazines or books fed to the shredding rolls.

Note the different speeds of the two rolls, which is indicated by the difference in size of the pulleys F and G. This machine will shred 3 to 4 tons of magazines per hour. No repairs or maintenance charges have been necessary in mills that have had this type of machine for as long as five years, and no labor is required for attendance.
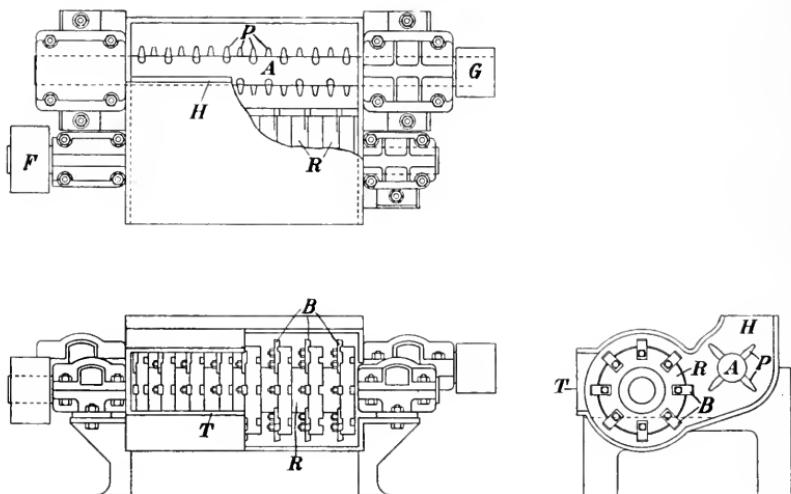
42. A Powerful Shredder.—The writer visited a mill that had recently installed a new type of paper shredder. The work being performed with this machine was quite remarkable. Large 35- to 40-pound books, from which the covers had been removed, were fed to the shredder and cut into almost a million pieces, not over 1 inch square. The shredded papers are expelled from the machine by a strong suction of air; they are then sent through a rotary-screen duster to a fan duster, which blows the papers to the cooking tanks.

This shredder, shown in Fig. 9, is a massive machine, weighing 8500 lb. The cylinder A is 30 inches long, and carries 20 knives B (only 4 are shown in the cut) that cut against 4 stationary knives C, located under the lower half of the cylinder and set in the frame. The cylinder is 36 inches in diameter, and makes 650 to 860 r.p.m. The length of the cutting edge of the revolving knives is 6 inches, and of the stationary knives about 38 inches. Consequently, when the paper stock is fed into the machine, it is

cut a number of times, and it is reduced to a uniform product that is easily handled with an air blower through an 18-inch pipe. The feeding spout D is a combination of inclined and vertical sides; E is a conveyor-belt roller.

The power required to operate the machine depends on the quantity of paper to be shredded. It is recommended that 50 h.p. be available when the production is 3 to 5 tons per hour, and that about 10 h.p. additional per ton of increased production per hour be available, up to the maximum capacity of the machine, which is 10 tons per hour. Hence, when operating at full capacity, $50 + (10 - 5)10 = 100$ h.p. should be available, though not necessarily used. On the date of the visit,
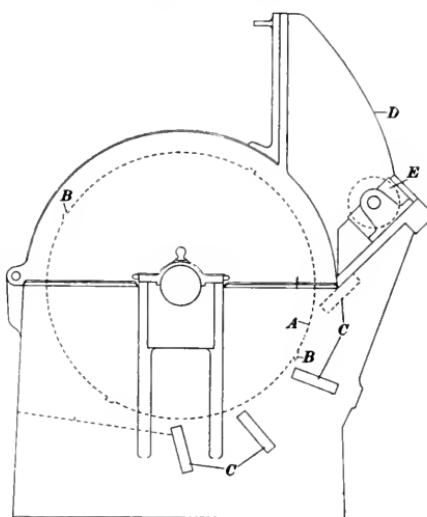
Fig. 9.
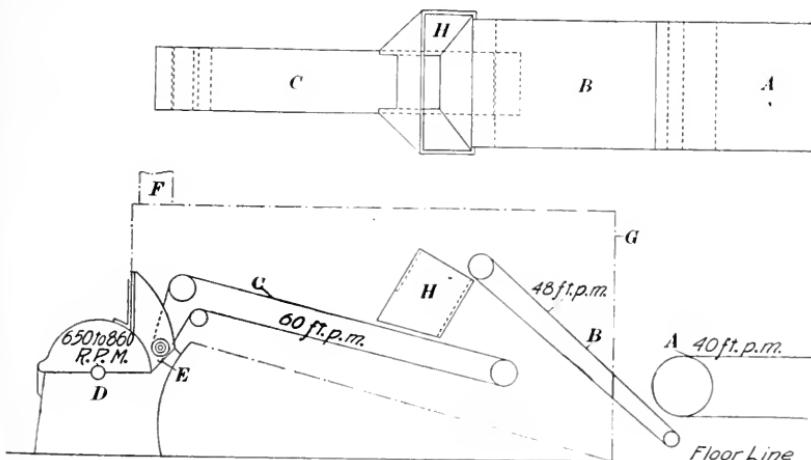
Fig. 10.

the machine was producing 4 tons per hour; and it was computed from the ammeter readings that 35 h.p. was being used. Fig. 10 is a layout of the conveyors used to feed this machine properly.

A belt conveyor A brings stock direct from the waste-paper sorting room and delivers it to a rubber-belt conveyor B, which delivers it to a hopper H, from whence it is conveyed to the shredder D.   The papers are shredded and separated thoroughly, so that all impurities will be removed on passing through the fan duster.   A leather scraper E keeps the paper from following the conveyor, and a pipe F carries the dust to the blower, which removes it from enclosure G.

HANDLING SHREDDED PAPERS

43. Dusting Old Papers after Shredding.—Strange to say, the subject of dusting the old papers receives but scant attention; it is usually regarded as a mechanical process of dumping old papers through the apparatus, and no further thought is given to it.   In reality, dusting and screening loose dirt from old waste papers by the fan duster in the dusting room, bears the same relation to the resultant finished paper that removing bark and rotten wood from the pulp wood bears to the production of fine, clean pulp.

To produce paper free from dirt, it is necessary to remove the greatest amount of dust and dirt at the initial stage of the process. If the duster delivers thoroughly dusted papers, the subsequent steps will be greatly simplified.   The cut and torn papers from the shredder should be given a thorough dusting, using a machine of the types described in Arts. **31** and **32,** or even a single wire-screen cylinder.

44. Prevention of Clogging.—The variation in the rate of feeding of old papers to the dusters is an important point to be considered.   The apparatus is built for a certain capacity, say 2500 to 4000 pounds per hour.   Below the minimum and up to the rated capacity, the papers are delivered from the duster in good condition; that is, thoroughly disintegrated and dusted.   But it sometimes happens that 4000 to 6000 pounds per hour are forced through the machine, causing it to become clogged, when it is liable to become dangerously overheated, by reason of the increased friction.   The dust cannot then be properly handled by the exhaust fan, and it fills the air, making it almost impossible to live in such an atmosphere.   As a consequence, the papers

will come out still dusty and dirty, through this overburdening process.   To correct this, the dusting capacity should be increased, and the screening area of the rotary screen should be enlarged, to produce thoroughly dusted papers.

PURCHASING PAPER STOCK

COST CONSIDERATIONS

45. Reducing Cost of Sorting.—By using a few precautions, it is possible to reduce the first cost in the reclaiming of old papers. The first essential in reducing cost lies in the purchasing of old paper stock.   Since the quality of the product of the mill is governed by its constituent materials, in other words, by what enters into the composition of the paper made, very careful and judicious selection of the waste-paper stocks is a prime requisite. Orders should be placed only with reliable packers, those that are known to live up to their guarantee of doing an honest business. It would be well to visit these packers at their sorting and packing rooms, noting the care they give to the handling of the papers as received, their equipment, and the amount of business that they conduct.   Packers should receive specifications covering a strictly uniform, clean grade of papers, and they should follow out these orders to the letter.   The Salvation Army has gone into the waste-paper business quite extensively, and their packings enjoy the reputation of being carefully graded and free from groundwood.   They command a higher price for their wastes; but it is cheaper in the end to use their stock, or to buy of similar conscientious packers.

In purchasing paper stock, the only consideration of the purchasing department should be to buy only that stock which can be recovered to meet the standard grade of the mill and which can be delivered to the paper-machine beaters at the least cost per ton, as received.   The method of getting the information for purchasing on this basis, as practiced in a Wisconsin mill, is to have the laboratory or testing department make a time, quality and shrinkage test on a unit lot of the paper offered on the market.   These tests are then turned over to the accounting department, which estimates the cost per finished ton for the

various grades. An example showing records of these tests is given below.

Name	Gross weight of bales (pounds)	Weight and kind of baling (pounds)	Weight of dust (pounds)	Weight of bags and unfit paper sorted out (exclusive of baling) (pounds)	Weight of paper put in stock tank (pounds)	Weight of 60% caustic soda put in tank (pounds)	Weight of 60% caustic soda recovered (pounds)	Weight of 60% caustic used (pounds)	Time of cooking (hours)	Time of washing (hours)	Time of bleaching (hours)	Weight of 35% bleach used (pounds)	Weight of air-dry stock recovered (pounds)
A	8780	57, bags 382, paper 9, wire	19½	14, string 307, G-W paper	7991	277	102	175	9¾	2½	½	113	5087
B	9031	230, bags 6, wire	20	5, string 859, G-W paper	7911	268	61	207	10½	2½	½	113	5217
C	9707	31, bags	20	269, G-W paper	9386	311	31	280	10½	3	½	113	6353
D	8666	122, bags 27, wire	19	298, G-W paper	8200	293	37	256	10½	3½	¾	113	3707

SUMMARY OF ABOVE TESTS

(All figures based on weight of paper as shipped)

Name	Shrinkage in sorting room (%)	Shrinkage in rest of process (%)	Total shrinkage (%)	Girl-hours per ton for sorting
A	8.85	32.24	42.09	30.9
B	12.40	29.83	42.23	22.2
C	3.31	31.25	34.56	10.8
D	5.38	51.85	57.23	15.7

46. Choice of Stock.—Only solid magazines, over-issues, unstitched, school books and solid ledgers, together with lithograph and shavings should be used, to reduce the cost of sorting. These grades require the separating of the heavy colors only, and a sorter can easily handle 3500 to 5000 pounds per day. The shavings can be added directly to the beater, provided they are unprinted, and there is sufficient beater capacity for completely brushing out the fibers; sometimes shavings are first put through a pulper. Instead of trucking the papers after sorting, they can be sorted directly onto and delivered to the dusters by conveyors.

In place of tearing magazines and books by hand, the work is accomplished better and more quickly by using machinery.

IMPROVING QUALITY AND USING DISCARDS

47. Improving Quality.—The exclusive use of the grades mentioned in Art. **46** would increase the quality of the product, which would be more uniform in color and in cleanliness. The composition of the stock being constant, the subsequent cooking, washing, and bleaching operations would not be so variable. Paper free from groundwood specks and undissolved ink would be obtained, and an increase in price of from 50 to 75 cents per hundred pounds could reasonably be demanded. Further, because of their freedom from dirt particles, samples could be duplicated, a procedure not otherwise practicable. Finally, by employing the cutter for tearing and shredding these grades of papers, the labor now engaged in this work could be decreased 40% to 50%, without decreasing the output of the sorting room.

48. Utilization of Discards from Sorting.—The discards, which may average 40 to 50 tons per month, are properly sorted into classes; this is done in the sorting room, and necessitates no additional help. The print is usually separated into what is called *white print* and *colored print*. White print is sold as such to mills making cheap blanks and liners; colored print and heavy colors are usually sold for making into boards, and this is also the case with book backs. Occasionally, all these discards are worked over at the mill in which they originate, with about 10% of unbleached sulphite, which serves for making a fairly good quality of heavy card wrapping for shipping rolls, etc. However, considering the amount of dirt that must necessarily enter into this grade, and which pollutes the entire mill with refuse, it is not a paying procedure, since a much better grade of sulphite fiber wrappers may be made at almost the same cost.

The colors might be sorted to each color—such as blues, reds, greens, browns, yellows—and cooked separately, washed and partly bleached, and then worked over into colors again. Since a majority of the fibers of these colored papers is made up of soda and sulphite, a sheet could thus be made that would sell for a good price. The only drawback might be that only a limited amount of stock of each color could be obtained, with the consequent problem of disposing of small lots. Since deduc-

tions are made for excess discards when paying the original invoice of the paper stock, it is safe to say that it is more profitable to sell the discards outright, and there is no attendant loss in doing this.

QUESTIONS

(1) Explain the differences in the layouts for bench sorting and for carrier, or conveyor, sorting.

(2) What chemicals are used to detect the presence of mechanical pulp in waste papers?

(3) About how much dust is obtained from the dusting of waste papers?

(4) Why is it unwise to overload the dusters that handle the cut and shredded stock?

(5) How can the purchasing department help the superintendent to get better results from the treatment of waste papers?

COOKING, DE-INKING AND DE-FIBERING

COOKING PROCESSES

OPEN-TANK PROCESS

49. Methods of Cooking.—The methods for cooking and de-inking old waste papers that are now in use are few in number, insofar as the principles utilized are concerned. However, each mill usually employs certain variations, which it considers necessary for the successful treatment of waste-paper stock. The three oldest methods in use are: (a) Cooking in open- or closed-top stationary tanks; (b) cooking in cylindrical or globe rotary boilers; (c) cooking in horizontal-circulating cooking engines. These processes will now be discussed.

50. Cooking in Open Tanks.—This is by far the most usual method of cooking old waste papers; it is used extensively in a number of the older mills. It is designated the **open-tank process** because the cooking tank is not covered while the papers are being cooked. Most mills that use this process have their own ideas regarding the details, such as the strength of cooking liquor, time of cooking, kind of alkali to use, and temperature of the cooking liquor, and these differ very materially from the details of the original Ryan process (see Art. **8**). These differ-

ences are the result of many years of experience; and the mills
have, by degrees, reached the point where they now have sound
data for properly cooking old paper stock.

51. The Cooking Tank.—The **cooking tank,** or **bleach tub,** as
it is usually termed, is a stationary cylindrical tank B, Fig. 11,
built of $\frac{3}{16}$-inch boiler plate;
it is 10 feet deep, 10 feet in
diameter at the bottom, and
10 feet 1 inch in diameter at
the top. The plates are riv-
eted so that all projections
will be on the outside, in
order to make the inside as
smooth as possible. The tank
is provided with a solid
bottom C and a false bottom
D. The false bottom is made
of $\frac{3}{16}$-inch boiler plate, and in
8 sections, 4 of which, $D_1, D_2,$
$D_3, D_4,$ are shown in the
illustration. To enable the
cooking liquor to filter
through to the real bottom,
these sections are perforated
with $\frac{1}{2}$-inch holes, spaced 3
inches apart from one an-
other. This false bottom
rests on a cast-iron spider,
which has 8 arms $F_1, F_2,$ etc.
The spider rests on an octa-
gonal framework of wooden
blocks $G_1, G_2,$ etc., 6 inches
square in cross section. The
space between the two bot-
toms serves to contain a large
volume of liquor, which is
forced up the 8-inch central

Fig. 11.

pipe H by a steam injector K, when the cooking is in process. The
arms of the spider are riveted, or otherwise fastened, by a flange
L to the central pipe H. The top of the central pipe, which is
about 9 feet long, is equipped with a baffle plate P, 10 inches in
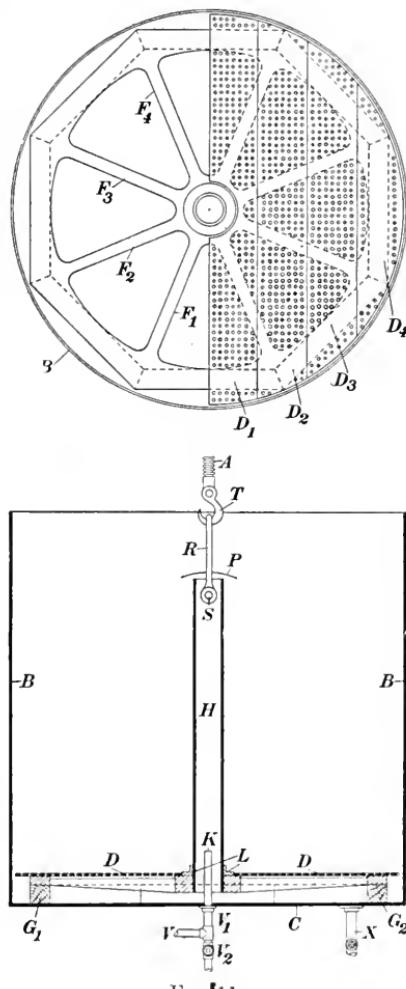
diameter, the under side of which is slightly concaved.   The baffle
plate is so designed that the liquor striking it is sprayed out-
wards and downwards, thus covering the entire exposed surface
of the stock in the tank with a shower of liquor.   Near the top
of the pipe is a U-shaped hook or bale R, of $1\frac{1}{4}$-inch round steel,
fastened by bolt S, for attaching hook T of the hoisting mechan-
ism; hook R is allowed to swing downwards when not in use.
V is a $1\frac{1}{4}$-inch steam inlet, V_1 is a $1\frac{1}{2}$-inch pipe, V_2 is a $1\frac{1}{2}$-inch
plug valve for drain, and X is a 4-inch washout valve.

The lifting mechanism is supported conveniently by erecting
a pier or column on either side of the tank.   A spur shaft carries
two sets of pulleys, one for raising the spider slowly and the other
for lowering it rapidly.   The pulleys are belted to a main shaft
that is situated at a convenient distance from the spur shaft.
One open and one crossed belt are used.   The spur shaft carries a
bevel pinion that meshes with a large bevel gear, which turns
like a nut on the long screw A, and lifts or lowers the spider.
Over each tank is placed a hood, which has a vent for carrying
off the steam and fumes.

52. Furnishing the Papers.—After being thoroughly dusted,
the papers are discharged onto a conveyor belt, which carries
them to another belt on the floor above the cooking room; this
latter belt brings the papers to chutes, which may be arranged to
deliver the papers directly into the tanks; or the papers may be
charged in armfuls at a time, by two men.   This latter method
may at first appear to involve extra labor and time; nevertheless,
it is the better method, because of the more uniform distribution
of stock.

53. Furnishing and Heating the Liquor.—Before beginning to
furnish (charge) the papers, the liquor is made up to strength,
and the correct volume of liquor is added to the cooking tanks.
It is then heated, by injecting steam under the false bottom, to
about 200°–210°F.   At this temperature, the liquor is forced up
the central pipe and against the baffle plate, and is sprayed out-
wards and downwards, in a full circle, over the entire upper
surface of the stock.   The spraying process is intermittent; it
occurs only when the pressure of the steam under the column
of liquor in the central pipe overcomes the weight of the volume
of this liquor in the pipe, and projects it upwards against the
baffle plate; and it continues until the *excess* pressure falls and

becomes zero. The liquor then filters through the papers or runs down the sides of the pipe or the tank, returns to the bottom, and forms a new and cooler (also heavier) volume of liquor for the steam pressure to work against.

54. Dry Cooks.—The spraying action should be so regulated as to occur about 4 to 6 times a minute during the period that the papers are being cooked. Evidently, this spraying must occur more frequently while the papers are being furnished to the tanks, and it is then increased to about 10 to 15 times per minute. For this reason, some mills decidedly oppose continuous furnishing of papers direct from the chutes. They claim that papers falling continuously are not evenly distributed around the tank, that they are liable to become bunched or packed, forming pockets of dry papers that do not come into contact with the spraying liquor. This results in what is termed a **dry cook** or *bad bleach;* the ink is not acted upon, the sizing of the papers and the oily vehicles of the ink are not thoroughly saponified, and on the later washing of the papers, it is impossible to wash off all the ink and secure a clean, white pulp.

In addition to the presence of the ink particles, another bad feature of a dry cook is that the paper itself, by not coming in contact with the liquor, will not be entirely reduced to a pulpy mass in washing, and it will not be thoroughly brushed out during the short treatment it receives in the beaters. Still, a considerable percentage is fine enough to pass lengthwise through the machine screens; and, on being made into paper and calendered, these dry particles cause a mottled or blocky appearance in the finished paper. These troubles are attributed to the method of scattering the papers across the top of the tank. The remedy is to furnish the papers, particularly hard-sized ledger and lithograph, in scattering armfuls; the papers are thus evenly distributed, and they all become saturated with the spraying liquor before the next armful is thrown in the same place. With soft-sized magazine and book stock, the papers may be delivered from the chutes directly into the tanks; they are then raked and distributed evenly over the path of the spraying liquor by two men, one on either side of the tank.

55. Preparation of Cooking Liquor.—In preparing a new cooking liquor, or fresh bleach, 1200 pounds of soda ash are dissolved in

water, heated, and agitated until thoroughly dissolved; sometimes the equivalent in caustic soda is used instead of soda ash. This operation is carried on in the alkali room, on the floor directly above the cooking, or bleacher, room. The liquor is run from the dissolving tank into the cooking tank, which has previously been cleaned out and made ready for the new alkali liquor. Fresh water is turned into the cooking tank until it reaches a depth of $4\frac{1}{2}$ feet; with a tank 10 feet in diameter, this is equivalent to a volume of 2644 gallons, or a strength of liquor containing $1200 \div 26.44 = 45.4$ pounds of soda ash to 100 gallons of cooking liquor. With a hydrometer, this liquor should test 9.15°Tw. or 6.34°Be., at 60°F.; at 180°F., which is the temperature at which the mill test is usually made, the reading should be 3.15°Tw. or 2.24°Be.

This strength of liquor will thoroughly cook 6000 lb. of ordinary soft-sized book and magazine paper. After long years of practice, this amount of alkali has been observed to produce the best results, and it is taken as the standard for this grade of stock. For cooking hard-sized ledger and deep-colored, hard-sized lithograph papers, the strength of liquor customarily used is 6.9°Be. or 10°Tw. at 180°F.; this reduced to 60°F. gives a reading of 10.7°Be. or 16°Tw. This reading is equivalent to 7.57% of soda ash by weight, or 1750 pounds of soda ash is required to be used to give this test.

While this amount of alkali is excessive, it is not considered economical to reduce it; because the cooked papers might then show defects of one kind or another, and these would at once be attributed to the way the paper was furnished and to the wrong strength of liquor used.

56. Before allowing the papers to be cooked over night, the liquor is again tested. A sample is taken while the liquor is being sprayed over the papers, and hydrometer and thermometer readings are also taken. By referring to the scale of corrections for the temperature, it is an easy matter for the alkali man to ascertain whether or not the liquor is up to the required strength; if not, he at once adds more of the alkali solution. All the liquors are tested, and the results are recorded on the daily report sheets, together with the amount of alkali used for each cooking.

57. Duration of Cook.—The operation of filling each tank usually takes $1\frac{1}{2}$ to 2 hours to furnish 6000 pounds of paper. This is

allowed to cook from 5 to 10 hours, even 15 hours, at times.   Light book and magazine can be thoroughly cooked in 7 hours, which is the minimum length of time in which it is possible to obtain good results.   When there is a shortage of paper stock, a tank is hurriedly furnished and is cooked for 5 hours, but the results are far from satisfactory.   Although most of the ink will have been acted upon, a small percentage will sometimes remain uncooked, and this will reduce the quality of the resultant sheet.

For most of the hard-sized ledgers and colored lithograph papers, 10 to 12 hours is considered sufficient, though if time is available, that is, if there is a large quantity of cooked papers ahead of the washers, the cooking time is increased considerably, even to 15 hours.   This length of time is possible, if the papers are furnished in the first tank filled in the morning; the tank will be filled by 9 a.m., and the papers are ready to be taken off by midnight.

58. Steam Used in Cooking.—The amount of steam used in the cooking of the papers is an important factor in estimating the cost of the process; but no definite data have been obtained as yet regarding the amount consumed.   The pressure on the main steam line is reduced by a valve to 30 pounds, the steam flowing through a $1\frac{1}{2}$-inch pipe to each cooking tank.   Here the pressure is again reduced by a valve, and the amount of steam used is regulated by the number of intermittent showers or sprayings of liquor that are desired per minute.

That the amount of steam used is excessive, is admitted by all those who have inspected the system.   At times, after all the liquor has been sprayed up, it fails to return quickly enough to form a seal below the false bottom, for the steam to work against; the result is that live steam continues to be injected upwards into the open air until this seal is again formed.   In a few mills, in order to retain the heat of the steam, the tanks are encased with wood or with an asbestos covering.

59. Reducing Steam Consumption.—To reduce the amount of steam used, it was suggested that the tank be covered with a wooden or iron cover while the cooking was in progress.   An opening 1 foot square was made in the cover, about 1 foot from the edge, and to this was attached a wooden outlet, which conducted the steam and vapor outside the building.   While this arrangement reduced very materially the amount of steam used, it

caused other troubles, due to excess condensation, etc., and it was discontinued.

One fact noted while using the cover on the tank, was the great difference in the amount of heat remaining in the papers, when they were ready to be taken off. The papers in the tank were so hot that it was necessary to allow the cook to stand and cool off, until the other cooks had been removed from their tanks. Even then, the papers were removed only with the greatest difficulty and discomfort.

Although the increase in the amount of heat retained by the papers adds to the difficulty of handling them after cooking, the heat hastens the saponification action; the ink is more completely broken up and dissolved, and it is more easily washed out in the washers; the tendency of the ink to collect into small lumps is overcome, because, after being subjected to the continued heat action, the particles of ink are very finely subdivided and will more readily form an emulsion with the cooking liquor. Also, since more than two-thirds of the hotter liquor is recovered, and much more drains away while the papers are in storage, the subsequent washing time for the papers is lessened considerably.

60. Removing the Cooked Papers.—After the papers have been allowed to cook the required length of time, the cooked papers are raised by a hoisting device that lifts the false bottom from the tanks. The hoisting mechanism is located on the floor above the cooking room. A 25 h.p. motor will furnish sufficient power to raise five cooks at the same time.

When the false bottom has been raised to within 6 inches of the top of the tank, it is stopped; the papers are allowed to cool, and the liquor drains back into the tank. Two men clad in the scantiest attire, consisting usually of overalls and wooden shoes, mount to the top of the papers and shovel them off with pitch-forks into large cars or containers, which are grouped around the sides of the tank. The work is laborious; it is also distasteful, because the steam that continually arises is filled with peculiar odors from the papers. It usually takes 2 hours to fork off 6000 pounds of the cooked papers, and the working time is limited to 5 hours for each man; the cost of handling the cooked papers is quite small.

61. Other Methods of Removing Papers.—A method of removing the cooked papers that has been tried and found to

be very satisfactory, is to attach 4 vertical rods, spaced equally distant apart around the false bottom; when the cook is raised, these rods form a kind of basket, and may be suitably fastened to an arrangement that will allow the entire mass of papers, still remaining on the false bottom, to be swung clear of the tank, onto a track system, and moved either by a crane or pulley over to a draining pit.   The false bottom is so built in this case that it permits dumping by turning on hinges.   After draining in the pit for some time, the papers may be fed into a hopper or kneader, located below the pit, which will so condition the papers that they can be pumped to the washers.

To accomplish this work with fewer men, one enterprising mill has laid a small, narrow-gauge, track system, sunk in a concrete foundation.   The tracks extend from the tanks to each washer in the beater room, and to side tracks in the bleacher room; the latter serve to store papers ahead of the washer.   By means of this track system, with small cars made to fit the rails, one or two men can easily convey the cooked papers to the washers.   Some mills have an electric truck, which has an arm that is run under the box of stock, lifts it, and carries it anywhere, with no manual labor at all.

62. Recovery of Chemicals.—The recovery of the alkaline cooking liquor used in the open-tank process is, perhaps, the best point in favor of this method of cooking old paper stock. The fact that no additional care, expense, or trouble is incurred in effecting the recovery of the liquor is also an attractive feature. Moreover, the cooking of paper stock is not nearly so satisfactory when done with fresh liquor as it is when part recovered liquor and part fresh liquor are used, because the soap or saponified oil that is contained in the recovered liquor has a definite and essential function to perform in emulsifying the carbon black and removing it in washing.

The rate of ascent during the raising of the false bottom carrying the cooled papers, is very slow; it generally takes 30 min. to lift the papers 10 feet.   This is a lifting speed of only 4 in. per min.; and it is so slow that nearly all the liquor not absorbed by the papers finds its way to the remaining liquor in the tank.   By thus slowly draining and running off the liquor, a varying percentage of the liquor is saved.   The degree of variation depends upon the nature of the papers, the soft, porous papers acting like a spongy mass to retain more liquor than the hard-sized,

stiff, rag-stock papers.   Another cause for variation is the loss of
liquor due to splashing over the side of the tank while spraying
with too great pressure of steam; also, when raising the papers, the
liquor continues to ooze out of sides, and drains down to the rim
of the top of the tank.   If there is no opening by which the
liquor can return to the tank, it will run over the sides and be lost
in the drain to the sewer.   However, with all these losses, the
average daily recovery is about $66\frac{2}{3}\%$ of the liquor used.   In some
cases, the recovery has been as low as 24% and as high as 92%.

63. Losses in Recovery.—Figures tabulated from exact data,
to show the variation in the percentage recovery of liquor that
occurs from day to day under ordinary conditions, with seven
tanks in use, indicated a maximum variation of 33.4% to 88.9%
of recovered liquor.   The monthly averages ran from 66.00%
to 78.03%.   Two tanks were furnished with new liquor during
this period.   The average recovery of soda-ash liquor on all
tanks was 71.34%, with 146 cooks.

In this tabulation, the variation was quite evident.   At first,
it was thought that the highest recovery figure, 88.9%, did not
represent the same value as the corresponding volume or per cent
of new liquor.   It was claimed that from 20% to 30% of the
alkali content was consumed in the saponification of the ink,
colors, and sizings, and that the condensation of the steam caused
the increase in the volume of the liquor.   It is true that there
is some decrease in the strength of the alkali content of the liquor
by saponification; there is likewise considerable condensation
while the liquor is being raised to the boiling point, though after
that, the steam acts only as a projecting force to spray the liquor.
The volume of steam and vapor given off on spraying is about
equal to the amount of steam injected into the tank.

As previously stated, there is a loss of liquor over the tanks in
spraying, and in the liquor that oozes from the sides of the
papers, while being raised, which fails to return to the tanks.
There is a further loss in the liquor that drains away while the
cars are standing in storage.   All this liquor, which now goes to
the sewer, could be very easily saved and recovered, and at slight
cost.   A concrete flooring, with grooved drains, would conduct
all this liquor to a common catch-all tank.   A catch pan could
be riveted to the top of the cooking tank, into which would drain
all the liquor that ordinarily goes to waste when the papers are
raised.

64. Increasing Recovery by Washing.—The percentage of alkali recovered could be further increased by washing the papers once or twice with warm water, while they still remained in the cooking tank.   This would necessitate draining off the liquor from the tanks before adding the wash water, in a manner similar to that of washing chemical pulp.   But this is not desirable, since the soapy liquor sticking to the papers acts to remove the carbon black, when put into the washing engine.   The strong liquor should be stored separately, and the wash water should be stored by itself in another tank; in this way, with a little care and attention, the strength of the liquors in all the tanks would be the same.   The strength of the recovered liquor could be determined, and its volume readily ascertained.   Then, by using the wash water to dissolve the correct amount of soda ash, and adding to the strong liquor, the strength and volume of the mixture could be brought up to the standard strength for cooking.

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ROTARY-BOILER PROCESS

65. Reasons for Using the Rotary-Boiler Process.—The cooking of old-paper stock in rotary-cylindrical and rotary-globe boilers is a later development that is viewed with great favor by all the newer mills.   The cleanliness of the cooking room, the absence of steam and condensation, and the ease with which the cooked papers are handled, are the great assets of this method.   The claim is also made that it is a much more economical process.

Although the saving in labor, both in filling the rotaries and in the subsequent washing operations, represents a very good return on the investment, the chief argument in favor of the rotary system is the uniformity of the cooked product.

The general arrangement of a cylindrical rotary boiler installation is shown in Fig. 12.   Details of the boiler are given in the Section on *Treatment of Rags*, etc.

66. Discussion of the Process.—The preliminary sorting and dusting is much the same as in the open-tank process.   A few mills have, very wisely, added cutters or shredders to their equipment, which help to condition the papers for the best results in cooking.   The tendency for the papers to roll up into thick wads, caused by the slow, revolving motion of the boiler, sometimes gives trouble.   These thick wads of paper are not

thoroughly saturated with steam and cooking liquor, and the result is the same dry cook mentioned in Art. **54.** To avoid this, the papers are first cut into short strips or are shredded into irregularly shaped pieces, that they may come more readily into contact with the liquor, and not roll up into wads.

However, improvement in the design of the rotary-cylindrical boiler in the last few years, has overcome the tendency of the stock to roll up, or ball up, into dry wads. Investigation has shown and practice has proved that, by increasing the number of the internally projecting pins and by staggering and placing them in proper positions, the rotary will not only cook thoroughly but it will also act as a de-fibering machine. In the 8×24-foot rotary, the present practice calls for a varying number of these rag or de-fibering pins, which are usually arranged in 5 to 9 rings of 8 pins each, the 8 pins being spaced uniformly about the circumference. The pins are made of $\frac{1}{2} \times 1\frac{1}{2}$-inch iron, bent to the shape of a U, and 9 in. high; they are riveted to the shell. The specifications formerly in use designated only about 9 or 10 of these pins. One mill that is equipped with this new type of rotary reports that it has abandoned entirely the use of cutters and shredders, and that it has even eliminated the railroad duster and the fan duster in its sorting and dusting rooms. Instead of using a 50- to 60-h.p. motor to drive the sorting-room equipment, as formerly, a small 5- to 10-h.p. motor now handles the load of the three or four sorting carriers, the papers are conveyed in their original condition directly to the rotaries, and a heavier cook can be handled. The charge has been increased from 7500–9000 pounds to 12,000–14,000 pounds.

Without a doubt, the older rotaries could not have accomplished what those of the newer type have done. It is a question, however, whether good judgment was exercised in discarding the dusting equipment at the mill above referred to. Dirt must be taken out some time; and the proper place is where the papers are dry and are in their original condition. Bearing in mind that the purpose of this mill was to keep the paper stock as flat and as compact as possible, the use of a revolving, tapering, cylindrical-screen duster would remove the surface dust by a tumbling action, and it would add but little, if anything, to the bulk of the paper stock entering the rotary boiler.

67. Fig. 12 shows the relative positions of the rotary and the dumping pit. Here R represents a typical 8×24-foot rotary; T
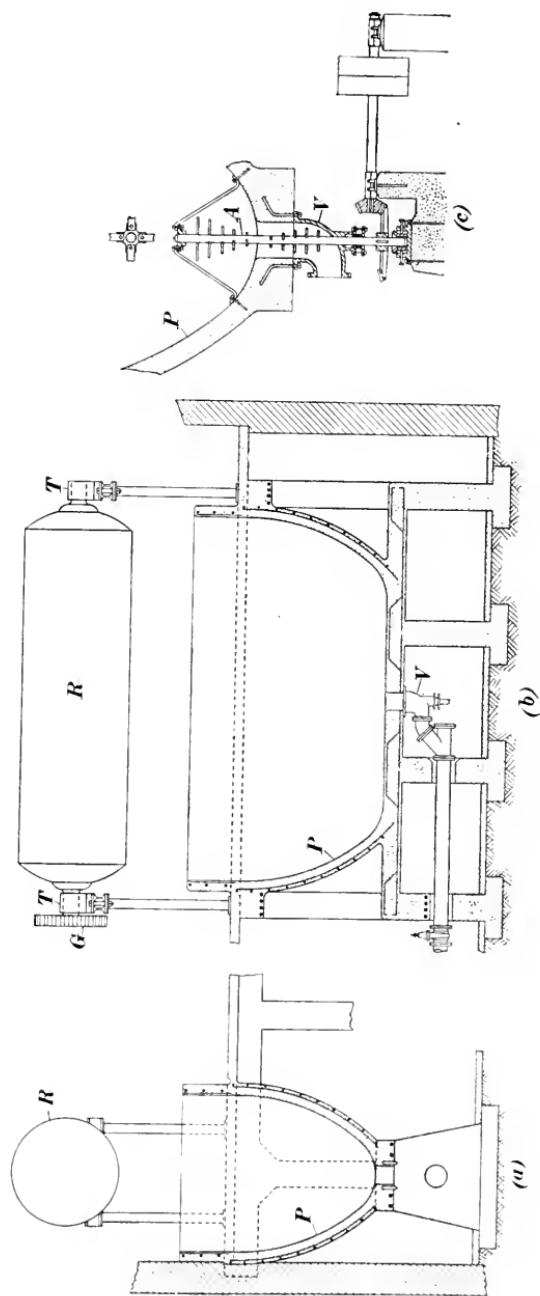
FIG. 12.

and T, the trunions, or bearings, one of which is hollow, for admitting steam; G, the motor driving gear; P, the dumping pit; V, the discharge connection. View (c) shows the agitator device A, used in modern pits for dumping of stock, and its drive.

68. Furnishing the Rotary.—After being discharged from the dusters onto a conveyor belt, the papers are delivered in a continuous stream to the manhole opening of the boiler. There is a difference of opinion in regard to the correct procedure for furnishing the papers and the liquor. In one mill, the practice is to furnish the papers first, packing them with long iron prodding rods; the liquor is then run in all over the papers. It is claimed that by this method the papers are more uniformly acted on by the liquor; also, opportunity is afforded for packing the papers, so they will not tend to float when the liquor is added, thereby decreasing the capacity of the boiler.

A second method in vogue is to furnish the papers and liquor together. In this way, it is thought that the papers are more thoroughly soaked with the liquor, and the possibility of a dry cook is overcome; also, the total time for filling the rotary is diminished, which is a valuable factor in costs and production.

A third method consists in running in the required volume of soda-ash solution first, and then furnishing the papers. The argument in favor of this method is that there will be absolutely no dry spots in the papers, and a much cleaner pulp will result, with a thorough cooking.

69. Amount and Strength of Liquor.—A rotary boiler 8 feet in diameter and 24 feet long is considered to be of the most efficient size for cooking old papers. A boiler of this size has a capacity of 1200 cu. ft., and it will hold from 5 to 7 tons of dry paper stock, depending on the grade and condition of the papers. Since the strength of the liquor used for cooking has never been standardized, the widest variation in this item is found in the different mills. Upon inquiry, one mill stated that they used water only as a detergent; another mill reported that they used lime and water; still another method in practice is dependent upon the action of a soap solution, together with a small quantity of free alkali.

70. An accurate statement from data received showed that another mill was using 3456 gallons of liquor per 10,000 pounds of paper; in this liquor was dissolved 1200 pounds of 58% soda ash

and 225 pounds of 76% caustic soda.   These alkalis are dissolved
in two tanks, each 7 feet in diameter and 7 feet deep, filled with
water to a depth of 6 feet, the combined contents being used for
one cook.   These tanks are equipped with a cover (an opening
$2\frac{1}{2}$ feet square being allowed for the introduction of the alkalis),
agitator arms, and a steam injection pipe.

A further report from one of the largest mills treating waste
paper stated that their consumption of soda ash amounted to
8% to 9% of the gross weight of the papers, as received in the
sorting room.   If an allowance of 10% be made for discards
on sorting, this consumption would be at the rate of 9 pounds to
10 pounds of soda per 100 pounds of net sorted papers.

The lack of uniformity in the amounts of soda ash used for
cooking paper stock is readily perceived from the figures stated,
and no attempt has been made to standardize this figure.
During the last few years, however, when the price of soda ash
advanced to $3\frac{1}{2}$ to 5 cents per pound, this chemical was viewed
with more respect, and efforts were made to reduce its con-
sumption.   Mills that formerly used 8% to 10% are now using
4% to 5%.   Should the reduction stop at this latter figure, or is it
possible to go still lower?   Very careful experiments are being
conducted at one or two mills to determine this safety point.
Cooks have been made using 3%, with no bad effects; but this
low figure is not to be considered as a criterion for a standard,
since conditions are not always the same at all mills.   Too many
variables enter into the problem, which must be solved by each
individual mill to suit its own equipment and conditions.   It
is to be hoped that with the adoption of standard cost methods,
further research will be brought about in different mills, and that
the results obtained will be interchanged more freely.

71. Amount of Water Used.—In standardizing rotary cooking,
the volume of water used should be a known, constant figure.
From inquiries made at numerous mills, only one had in practice
a method of measuring the water.   Many mills stated that they
filled the rotary up to a *certain mark*, or else permitted a water
line to be open for a certain length of time.   Here, at least, is a
step that can be taken in the direction of a standard for uniform
operation—the installation of a water-measuring tank.

72. Rotary cooking accomplishes two things at the same
time; *viz.*, de-fibering and de-inking.   The de-inking has been

considered a chemical change, but it may also be classified as a physical change. The slow revolving motion of the rotary creates a tremendous amount of friction of surfaces, of attrition of particles of paper, and the combined action gradually separates the paper stock into its component parts—fiber, filler, size, and ink particles. With lapse of time, this action produces a colloidal solution, or suspension, of ink particles and fiber particles.

73. Increasing the Effect of Friction.—The question naturally arises—how can the friction between the inked surfaces of the paper be increased? Speeding up the number of revolutions per minute of the rotary may help, but only to the point where the stock gets the greatest tumbling action, and without clinging to the shell on account of the increased centrifugal force. Increasing the number of pins or angle bars may help; but it may have an adverse effect, if the rotary speed be not carefully worked out. The use of too much water will increase the slippage of the particles of stock upon one another, allowing the stuff to slip around without doing much de-fibering. Likewise, by not using sufficient water, danger of uncooked papers may be encountered. It would therefore appear that this factor in rotary cooking is a very important one; and careful supervision as to results obtained in using varying amounts of water will prove this statement. Cooked stock that is in a finely ground state, with particles not larger than a bean, and which has soaked up all the liquor possible to saturate it, with no residual unabsorbed or free liquor present, can be said to have had the proper consistency of paper and water during the cooking period.

74. Duration of Cook.—When the liquor and papers have been completely furnished, the manhole covers are bolted down and securely fastened. The steam is turned on and the rotary boiler is set in motion. A recent improvement in the construction of the rotaries provides for the regulation of the amount and frequency of the steam injections. An automatic valve is attached to the steam inlet, which operates and blows steam only when the pipes are submerged in liquor. The advantages of this arrangement are easily observed by the decrease in the amount of steam used, the more thorough cooking action, and the elimination of the possibility of scorching the papers with live steam.

75. Variation in the time of cooking and in the steam pressure used, is another feature of operations in different mills. The data received shows that the cooking time varies from 1 to 10 hours, and that the steam pressure varies from 10 to 50 pounds, One mill recommends cooking 6 hours under 40 pounds pressure, while another mill cooks 10 hours under 50 pounds pressure. A mill that makes a very good grade of paper reports that a minimum of 7 hours is required for a good cook, and that 2 hours extra is allowed to reduce the pressure, blow off the liquor, and dump out the papers. The cooking in this case is conducted under 20 pounds pressure.

The variations here noted are attributable to the different procedures in practice. In the practical application of rotary cooking, it is generally conceded that there are three distinct factors that enter into the correct cooking of the papers. These factors are: (1) Volume and strength of cooking liquor per 100 pounds of paper to be cooked; (2) time allowed for cooking, exclusive of time necessary for blowing off pressure and dumping papers; (3) steam pressure used in cooking.

These three factors balance one another. If any one of the three be varied, the other two must be varied also, but in the reverse or opposite direction, to make the balance perfect again. The data received from the different mills establishes the truth of this observation. One combination shows: 1494 pounds of soda ash in 3500 gallons of water per 10,000 pounds of papers, cooked 7 hours, at 20 pounds pressure; a second combination is: 14,000 pounds of papers, cooked 10 hours, at 50 pounds pressure, in a weak solution of soda ash.

76. Dumping, or Emptying, the Boilers.—The construction of the rotary boiler is so arranged that when the boiler is revolved and stopped, with the manholes facing downwards, the cooked papers discharge from the openings, the manhole covers having been removed. There is sufficient incline on the inside of the boiler to cause the papers to be removed almost entirely by gravity. The few remaining papers, if any, are raked out with a long-handled iron hook.

The papers are discharged below the rotaries into dumping or draining pits. Some of these pits, or tanks, are equipped with a perforated strainer, which allows the liquor to drain off into a separate catch pan, to be used over again, if desired, in making up the new liquor for the next cook. The dumping pit is

equipped with two washout valves, one draining valve, and one large outlet, for the removal of stock to the washers.

77. Recovery of Liquor.—The recovery of the soda-ash liquor used in rotary boilers is apparently lost sight of; but, inasmuch as the papers absorb most of the liquor, there is only a relatively small volume that freely drains off into the dumping pits. The papers treated in a rotary are reduced to a pulpy consistency, due to the continued rubbing and grinding action. The pulpy mass acts like a sponge, and will absorb and hold, by capillary attraction, a large volume of water; consequently, unless it is allowed to drain for a considerable period, the recovered liquor will be a small item.

The data collected on the recovery of the liquor gave results that varied from 11% to 50%, the general average being about 30%. One mill reported that they did not expect to recover any of the cooking liquor; it was worthless, in their opinion, and would merely discolor any fresh liquor that was made for new cooks. A second mill reported the average to be approximately 15%; and a third mill observed that the average was, roughly, 33%, or one-third of the liquor used.

78. A very enterprising mill stated that they had been *thinking* about this loss of soda ash for a number of years, but had done nothing definite to prevent it. They employed a chemist, who advised them further concerning the value of this waste, and they immediately took steps to provide a suitable drainer and catch pan for the liquor. In the dumping pits, the cooked papers are now subjected to a wash of warm water after as much as is possible of the cooking liquor has drained away. When the first wash water has drained off, a second wash water is applied; in this manner, the recovery was increased to 60%. Such efforts will pay, no doubt, when 8% to 10% of soda ash is used, and when the price of soda ash is high; but it is a very debatable question when only 3% of soda ash is used, as is now frequently the case. The cost entailed in saving the waste may be greater than the cost of the chemicals saved.

79. Spherical Boilers.—This type of cooker is operated in the same manner as the cylindrical type. An illustration of a spherical, or globe, boiler is given in Section 1 of this volume.

80. Power Required.—The manufacturers recommend the use of 8 h.p. for an 8 ft. $\times$ 24 ft. boiler; but actual practice has shown

that $4\frac{1}{2}$ h.p. is sufficient.   One installation of this size of rotary
calls for a 5 h.p. motor for each rotary, and the motor is seldom
called on to approach its rating.   The boiler revolves so slowly,
about 1 revolution every 2 or $2\frac{1}{4}$ minutes, that the driving power
required is small.

81. Furnishing Cooked Papers to Washers.—After the cooking
liquor has drained off as much as possible, the papers are ready
to be furnished to the washers, and this is effected in one mill by a
very ingenious arrangement.   It was previously stated that it
required the combined efforts of six men to move the loaded cars
of cooked papers to the washers when the open-tank method of
cooking was used.   In the mill here referred to, in which rotaries
are used, the dumping pit is equipped with a dumping valve that
leads into a vertical cylinder, about 3 feet deep and 2 feet in diam-
eter, placed directly under the dumping pit and equipped with
agitator propellor arms that are driven from a separate motor.
The pulpy, cooked papers flow toward this cylinder, and they are
hastened along by a water-pressure hose line.   In the cylinder,
they are agitated, to prevent any clogging of the pipe line through
which the papers are pumped direct to the washers.   This
procedure effects a great saving in time, in labor, and in cleanli-
ness of the cooking and washing rooms.

Fig. 12(c) shows a cross section of an agitator device A now in
quite common use in the more modern mills; it is a very simple
arrangement, and is entirely satisfactory in operation.   A careful
examination of the drawing is a sufficient explanation of the
construction.

82. Remarks Concerning the Rotary Process.—The rotary
process for cooking old-paper stock, and the dependent methods
of handling the cooked papers, is regarded as the most convenient,
the most efficient, and the most practical method in use.   This
view is held, in particular, by those mills that have rotaries in
use or which expect to install them.   While initial cost is con-
siderable, the absence of steam and condensation and of the
accumulation of papers and alkali liquors, the lessening of depre-
ciation throughout the entire process, and the decrease in the
labor cost attending the cooking and washing processes, are
considered to be factors that more than counterbalance the extra
first cost of installation.   The entire process is more healthful
to the workmen, and the cleanliness throughout appeals to all

who are familiar with other methods of treating waste papers. Some recent developments, however, have features which are strong arguments for the newer processes.

QUESTIONS

(1) State the advantages of a rotary boiler and explain the method of furnishing it.

(2) How much soda ash is commonly used per 100 lb. of paper cooked?

(3) Why is the amount of solution used so important?

(4) How does the rotary help to de-ink waste paper?

(5) What is the next step after the cooking is complete?

COOKING-ENGINE PROCESS

83. Description of Cooking Engine.—The **cooking engine** for waste papers is a machine of the type shown at A, Fig. 13; it is essentially a variation of the beater or washer described in
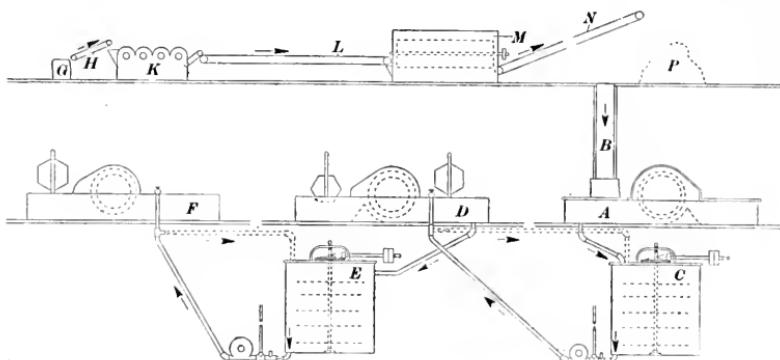
Fig. 13.

Sections 1 and 3 of this volume. An elliptical-shaped tub, about 8 ft. × 20 ft. and 3 feet deep, is divided down the center by a midfeather, and in one side of the channel is a beater roll or propeller. The tub is covered as tightly as possible with steel plate, the end covers being hinged and held down by bolts or clamps.

Waste papers are prepared[1] as previously described; they are stored on the floor above or in bins, and are furnished by a chute B, Fig. 13. The cooking liquor, usually a dilute solution of soda ash,

[1] In Fig. 13, G is a bale of papers, H a belt conveyor, K a railroad duster, L a sorting conveyor, M a fan duster, N an inclined conveyor, P a pile of prepared stock.

is run into the engine A until the alkali content is equivalent to 10% of the weight of the papers that the engine can handle. This amount will fill the tub to a certain depth, say half full. The papers are then furnished and are circulated by the roll or paddle, and they are soaked with the liquor at the same time. Water is added as necessary, and more papers are fed in until the desired consistency, about 6%, is reached. A charge is about 1200 lb. of papers. While the charge is being furnished and washed, the contents are heated by steam, at full boiler pressure, for about $1\frac{1}{2}$ hours. The agitation created during circulation de-fibers the paper and assists the chemical action of the liquor in loosening the ink particles, which are removed in the subsequent washing. The cooking time is about 2 hours, varying somewhat with the grade of the waste papers; old ledger and the like require a longer time to disintegrate. The power required is used almost entirely for circulation, and will average 25 to 30 h.p.

84. When the papers are thoroughly cooked and re-pulped, a valve is opened, and the pulped papers are allowed to flow into chests C, Fig. 13. No attempt is made to recover any of the cooking liquor, as it is considered not to have any value. The papers are furnished to the washers D by pumping from the chests C into which the papers were dumped after being cooked. After washing, the stock goes to chest E, from whence it is pumped to the beaters F.

85. Advantages of the Process.—The cooking engine process is claimed to have the following advantages: (1) Dusted papers are furnished from storage direct to engines; this provides for a storage always on hand, and it calls for a minimum of labor for furnishing. (2) Engines are covered tightly; this saves in steam and heat. (3) Papers are re-pulped better than in the old type of rotaries; this lessens the amount of work required later for beating and brushing out in washers and beaters. (4) Papers are thoroughly soaked in the cooking liquor; there is here no possibility of a dry cook. (5) Papers are handled by gravity, both before and after being cooked; this eliminates the hand labor—a costly item in the open-tank process. (6) Small labor cost throughout.

What may be called disadvantages or costly features are: (1) No recovery of the cooking liquor; this results in a large consumption of soda ash. (2) A large amount of steam is used; full

boiler pressure is maintained for $1\frac{1}{2}$ hours. (3) Large expen-
diture of power is required to circulate the papers. (4) The oil
consumption and belting wear and tear is large; extra with belt-
driven pulleys. (5) General wear and tear and depreciation are
greater. (6) The pulp product is considered to be weaker; caused
by the violent action of the steam, alkali, and the brushing action
on the pulp. (7) Poor color of recovered pulp, compared with
open-tank pulp, and not as good as rotary pulp.

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A SEMI-MECHANICAL PROCESS

86. Treating Old-paper Stock Mechanically.—A new (patented)
method has recently been perfected; it is in use in a few places,
but has not as yet been completely adopted in the older mills.
This method is largely mechanical in its action, and the details
are illustrated in Figs. 14 and 15. The advent of this machine gave
a wonderful impetus to the idea of treating paper stock mechanic-
ally. There is now quite a varied line of processes that might be
thought to have originated from the idea of propeller de-fibering;
these will be considered later.

87. Description of the Process.—This process was first brought
to the attention of the general public in 1914–1915. Fig. 14
illustrates the design of the
machine, which consists of an
inner cylindrical tank A that
leads, at its bottom, into a
draft tube B, through which
extends lengthwise a shaft F,
to which are fixed two pro-
pellers C and C_1, spaced apart
from each other, and of differ-
ent pitch. The propellers,
which are rotated at about
2000 r.p.m., draw the material
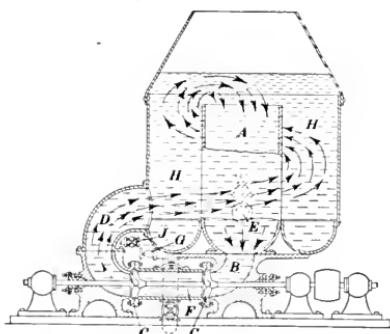
Fig. 14.

downwards from tank A, drive it through tube B, and up through
the course D at high velocity, estimated at 1200 ft. per min.

The course D discharges at a tangent into an outer chamber H,
which surrounds the chamber A and is concentric with it. The
material entering chamber H at a tangent circulates and rises
spirally therein, as indicated by the arrows; it then cascades over

the upper edge of chamber A, and repeats its course of circulation through draft tube B, propellers C and C_1, and chamber H.   The machine maintains a perfect circulation until all the stock is de-fibered.   The stock is withdrawn from the apparatus through suitable pipes G, which lead from the mid length of the tube B and from the bottom of chamber H, as shown.   During the feeding of the machine, water is supplied through pipe E, and steam for heating is admitted at intervals, as needed, through pipe J, shown below the course D.

The de-fibering action is due to the propellers C and C_1, which revolve so rapidly that the water is unable to take up the rotary speed thereof.   Consequently, there are two opposing forces, one being caused by the speed of the propeller and the other by the inertia of the liquid and stock.   In addition to these two de-fibering forces, there is another action, which may be described as the constructive and explosive effect on the fibers that is caused by the difference in the pitch of the two propellers C and C_1.   The blades of propeller C have a greater pitch than those of propeller C_1, which creates a tendency to form a vacuum between the two propellers, thus producing what is described as an explosive or disintegrating effect on the stock.

88. De-inking Action.—As to the de-inking action, it appears that when wet paper that has been printed with ordinary black printers' ink is torn, any ink that is on the line of tear is much loosened by the pulling apart of the paper fibers; so much so, in fact, that the adhesion of such portions of the ink as remain on the fringes of disengaged fibers at the torn edges is much less than the normal adhesion of ink to untorn paper.   This is probably due to the fact that the dry black ink is, physically, a species of film or incrustation, which sticks to the paper by reason of the adhesive properties of the ink, but which is capable of being mechanically loosened by the relative motions of the wet matted fibers to which it is stuck.   Now if the paper be torn into such fine bits that the paper fiber foundation to which each particle of ink adheres, is wholly or partly pulled apart,—that is, if the paper is completely pulped or de-felted,—then this loosening action affects all the ink and renders it easy to remove.

89. Character of Paper Produced.—Obviously, some types and grades of paper stock can be reduced to a pulp more readily and with less deterioration than others.   A pulp made from a free

stock, in which the fibers in the original paper making were not greatly hydrated, is, of course, felted together rather than stuck together, and it is much more amenable to a disintegrating or de-felting action than a paper made of over-beaten or slow stock, in which the fibers are so much hydrated and glutinous that they are more or less welded together as well as felted. Extreme examples of such papers are pergamyn or glassine papers.

90. Method of Cooking.—The following statement was obtained from a superintendent who had one of these machines under his direct care and supervision:

"We are at present cooking with 5% soda ash, using about 900 pounds of stock to a batch, and we take about 50 minutes to a batch, the density of which is around 5%. While one batch is in process, we are softening another in the tank above, using the exhaust steam from the turbine for heating. We raise the temperature to 160°–180°F., never guessing at it, but always using a thermometer, as we get the best results in this way."

91. Cost of Operation.—This superintendent further states: "As to the cost of operation, this is, indeed, a hard matter to determine. There is, of course, a saving of about 3% in soda ash, as well as the saving of time in washing, which may counterbalance to some extent the extra power consumption. There is also a big difference in the cost of handling, which is quite an item in the vomiting process; in fact, I may venture to state that this item was responsible for the advent of the rotary. There is also to be considered the matter of the elimination of the dirty mess caused by the dripping of the alkali from the boxes, and the condensation caused during the cooking process."

It may be remarked that a 75-h.p. turbine has been specified for the satisfactory operation of the process.

92. Advantages and Disadvantages.—The chief objection to this process, which was later raised at the above mentioned mill, was its consumption of steam for power and heating. Even though the stock traveled 1200 ft. per min. in this machine, it was found that dead pockets of stock remained in the machine and were not acted upon, which resulted in dirty paper stock; this happened from oversight or carelessness in not getting the proper density (that is, the correct proportion of weight of papers and volume of water) in the tank. If the charge were too heavy on entering the machine, only that portion around the central tube

circulated freely. It has been suggested that the chamber H be divided by a helical passage, so arranged that the stock will circulate around and around the central tube until it finally comes to the top and splashes over into the central tube again, to begin its journey once more. If given proper attention by men who can regulate the stock to a uniform consistency, this machine will produce a product that can be readily washed, screened, and made into good paper. The color is a blue white, though not any bluer than stock produced by any other mechanical process, such as the rotary boiler or any of the later centrifugal-pump and tank systems.

93. The amount of steam consumed is that required to raise the temperature of the water in the de-fibering machine to 160°F., and for no other purpose; this represents approximately 300,000 B.t.u. per 100 pounds of paper.

94. Layout, and Sequence of Operations.—With the exception that no provision for bleaching need be made, and that the boiler capacity may be limited to that required for any new furnish and for mixing the recovered stock with this new furnish, the process just described uses substantially the same auxiliary apparatus as would be used in any other process that employs a mechanical pulper. The sequence of operations is as follows: According to their condition, the papers are first sorted by hand or are dusted in a duster and afterwards sorted; the first procedure is used when the papers are reasonably clean. The papers are then torn and are again dusted in a railroad duster or its equivalent. The torn papers are next conveyed upwards by a belt, apron, or an air conveyor to a soaking tank having an agitator, in which they are thoroughly wet in water at about 160°F. This tank A, Fig. 15, is so placed that it can quickly charge the de-fibering machine, which works in batches. The water in tank A is preferably heated by the exhaust from a steam turbine that drives the machine.

The de-fibering machine B, Fig. 15, is the next element in the layout, and its general principle has been already sufficiently described. Quick-opening valves must be provided for rapid charging and discharging; the time required for these operations being, even under the most favorable conditions, a considerable proportion of the total time of operation. The pulp from the machine passes to the de-inked stock chest C; it requires washing

only, or, at the most, washing and brushing out in the Jordan, to render it suitable for delivery to the stuff chest. The washing arrangements, indicated at D, are of the utmost importance for removing the loosened ink. The washing layout differs more or less in details, according to local conditions; but with an arrangement of ordinary efficiency, the pulp should be washed for about 2 hours. The pulp from the final tank will be of 3% to 5% consistency; it can usually be pumped to the paper-machine chest, if unmixed recovered stock is to be employed; or it may be pumped to the beater or other receptacle, in which it may be mixed with
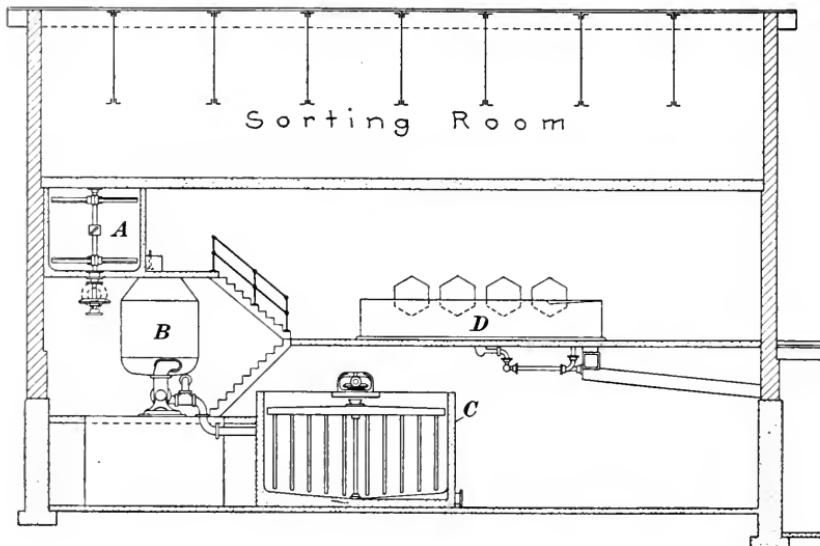
Fig. 15.

any new stock that is to be added. In some cases, it may be desirable to brush out the recovered stock in the Jordan before sending it to the stuff chest; the piping arrangements should be such that this can be done, or the Jordan should be by-passed, as conditions indicate.

Where magazine stock is treated, and sometimes in other cases also, it is advisable to pass the stock from the de-inked stock chest through a wire catcher, on the way to the washer. The washer may be an ordinary flat screen, or a long channel with dams, or a deep well. The well is made about 2 feet square and 25 feet deep, with a partition in the middle that reaches nearly to the bottom. The stock, diluted to about 1% consistency, is

fed at the top of one side, passes down, drops the pins, and is delivered near the top again.

95. Pulping Engine.—A pulping engine, which may be used in place of tank A, Fig. 15, in connection with the de-fibering machine just described, is shown in Fig. 16. This consists of an elliptical-shaped tub A, with midfeather B, in which the mixture of
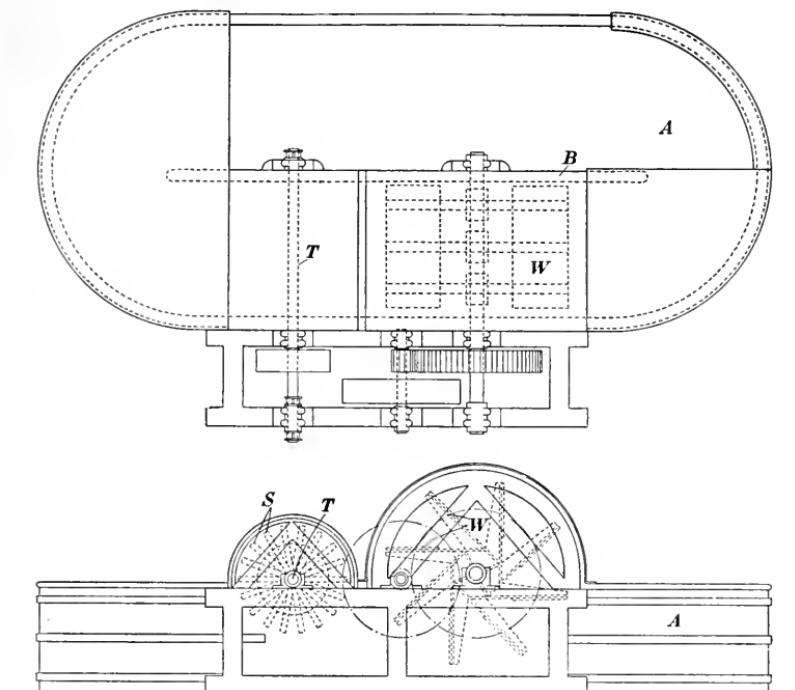
Fig. 16.

shredded papers and cooking liquor is circulated by a paddle wheel W, which makes about 19 r.p.m. The shaft T, which turns at 150 r.p.m., is studded with wooden slats S, which slash the paper into fragments and mix them with the liquor. One of these engines will hold 1700 pounds of paper, dry weight.

NEW TANK AND PUMPING SYSTEM

96. Remark.—During the World War, manufacturing methods and processes were given closer scrutiny than at any previous time. Work that required manual labor, and which had received

scant attention up to that time, possibly because of the abundance of willing workers at low wages, was supplanted by machinery and mechanical processes. It is therefore not strange that this change also occurred in the processes for the conversion of old-paper stock. After the introduction of the de-fibering process just described, many applications were made of the idea of de-inking and de-fibering paper stock by propelling and circulating with centrifugal pumps, and by impinging the stock and water against a plane surface, a conical surface, a Y or T surface, or even against itself, in divided streams.

97. Improved Cooking System.—One very enterprising mill that formerly used the open-tank system has installed a new system, which not only saves 50% of the building space, a very
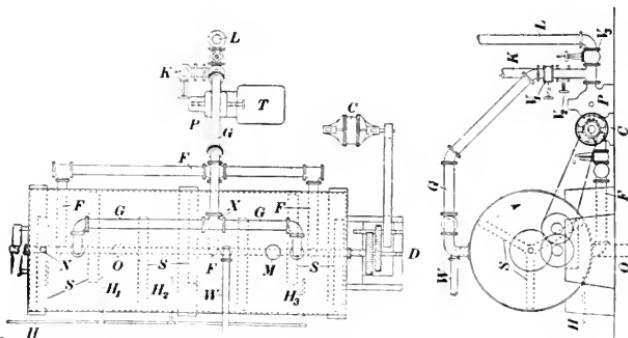
Fig. 17.

important item in costs, but also effects a saving of 50% in soda ash, and saves the services of 28 men and 30 women. This change was effected by using the old tanks in the new construction, by installation of the carrier system of sorting, and by combining what was formerly two sorting rooms and two cooking rooms into one sorting room and one cooking room.

Fig. 17 represents one of four similar cooking tanks, each 10 feet in diameter and 26 feet in length, suitably mounted on concrete piers. Each tank is equipped with a specially designed agitator, having arms S, which are staggered on the central shaft and are so arranged that complete agitation is assured at a speed of 10 r.p.m. The agitator is belt driven, and the power is furnished by individual 10-h.p. motors; the motor and the agitator drive are shown at C and D. Although 10-h.p. motors are used, actual

tests indicate that 3.5 to 5-h.p. is sufficient; but for safe working, it was deemed advisable to have a motor of sufficient power to take care of any unusual condition that might develop, as when more than 7500 pounds of paper stock is cooked and agitated at an increased density.

98. Method of Operation.—The paper stock, which has been previously dusted and shredded into pieces 2 inches square, is blown through an 18-inch diameter air duct from the sorting room into the charging manhole, shown at M, Fig. 17.   To allow the escape of air during the charging, a vent N is provided at the other end of the tank.   A 6-inch water pipe W supplies water to each tank while 6500 to 7500 pounds of stock is being introduced.   Soda ash to the amount of 4%, based on the dry weight of the paper stock charge, is dissolved in the soda-ash tank, which is located where convenient, but preferably on the floor above the cookers.   The filling operation takes from 20 to 30 minutes.   The temperature of cooking is maintained at 200°F., so that the consumption of steam is not so great as in the open-tank or rotary-boiler processes. The steam inlets are shown at H, H_1, H_2, and H_3; they are made of $\frac{3}{4}$-inch piping, reduced from a $1\frac{1}{2}$-inch line, on which the valve is located.   When properly filled with paper and water, the stock should have a consistency of 8%.

99. De-fibering and De-inking.—The de-fibering and de-inking of the stock are effected by an 8-inch centrifugal pump P, direct-connected to a 40-h.p. motor T.   The pump is especially designed for this work; it has impellers of sufficient rigidity, and is constructed to de-fiber and circulate, without plugging, at a speed of 1700 r.p.m.   Under the heaviest loads, 36 h.p. is required to operate the pump, but the average for 30 days was only 18 h.p.   However, when it is necessary for the pump to take up peak loads, such as an extra heavy wad or slug of stock, the extra power then needed is available.

100. The circulation of the stock is effected by means of 3 8-inch pipe lines F, which lead to the pump inlet, and by 2 8-inch pipe lines G, which lead from the pump discharge back to the cooking tank.   The pipes G conduct back to the top of the tank the stock that impinges on the T connection, shown at X, where further de-fibering takes place.   The T connection is considered to hasten the preparation of the stock, because of the friction

and the churning that the mixture of paper and water receives at this point.

After circulating, de-fibering and cooking for one hour at a temperature of 200°F., the papers are considered to be cooked. By opening valve V_2 or V_3 and closing V_1, the cooked stock is conducted by lines K or L to storage tanks, not shown in the figure. From 20 to 30 minutes is required to empty the cooking tank. The process consumes 30 minutes for filling, 60 minutes for cooking, and 30 minutes for dumping, a total of 2 hours, for 6500 to 7500 pounds of de-fibered stock. This compares very favorably with 5 to 10 hours for cooking 5000 to 6000 pounds of papers in the open-tank process.

101. Fewer Employes than with Open-Tank System.—A comparison of the labor employed with the improved system with that employed with the open-tank system shows that the improved system will do the combined work of two sorting rooms used with the open-tank process. Specifically, the old system requires 2 rooms for sorting on the bench method; 2 foremen; 6 carrier men, for emptying barrels onto conveyors; 4 truckers, for trucking barrels of sorted papers from benches to conveyors; 6 cook-room men, 2 to make soda ash and 4 to fill open tanks with papers; 4 unloader men, to remove cooked stock from tanks with pitchforks; 2 washer rooms, with 4 men in each room; 24 washer men, 8 men on each tour, to fill washers by forking stock from small cars; 60 sorting girls. This shows a total of 54 men and 60 women.

The improved system requires only one (1) room for sorting 60 tons of paper; the conveyor system replaces the bench method of handling the papers; and there is required: 1 foreman; 3 floormen, to truck, lay down, and open bales at the conveyors; 2 cook-room men, 1 to make soda ash and regulate steam and water, and 1 to fill and discharge cookers and to pump stock; 12 washer men, 4 men on tour in 2 rooms (2 men for each tour); 30 sorting girls. This shows a total of 18 men and 30 women, which is a reduction of 36 men and 30 women as compared with the open-tank system. A saving of two-thirds the number of men and one-half the number of women formerly required to produce the same tonnage, is a marked step forward in lowering manufacturing costs. The improved system is a distinct credit to the mill employing it, and unstinted praise is due to the superintendent who planned and worked out the process.

USE OF WASTE PAPERS FOR MAKING BOARDS

102. Use of Discards.—There is much waste paper collected that cannot be made into white paper; to this must be added the discards from the sorting processes previously described. Still, even this low-grade material is graded for special uses; it is highly valued for test board and wrapping paper and in the manufacture of kraft paper. Other grades of discards, including old box boards, etc., go into pasteboards, card middles and similar papers. Less care is required in sorting discards, and they are very often furnished direct to the beaters.

QUESTIONS

(1) Describe the cooking engine.

(2) Would you consider it worth while to recover the chemical used in cooking by the process described in Art. **87**? Give reasons for your reply.

(3) Upon what principle does the mechanical de-inking of paper by the process of Art. **87** depend?

(4) If 5% of soda ash is required for a batch of 900 lb. of papers, what is the weight of soda ash required? *Ans.* 45 lb.

(5) How is the de-fibering and de-inking of stock effected by the process described in Arts. **99** and **100**?

(6) Referring to Fig. 17, explain briefly the operation of the apparatus there illustrated.

(7) Mention some of the advantages that the improved system has as compared with the open-tank system.

TREATMENT OF COOKED PAPER STOCK

WASHING THE STOCK

103. The Third Step.—The third very important step in the treatment of waste papers pertains to the washing and the subsequent bleaching of the cooked paper stock.

104. Washing Engine.—Many different methods are used in washing the papers, the most general process being that in which washing engines are used. These engines, fully described in Section 1, consist of a beater-shaped tub, a circulating roll that is equipped with blunt steel knives, but without a bed plate, and 2 to 4 octagonal-drum washing cylinders (see Figs. 11 and 12, Section 1).

The capacity of this type of beater is from 800 pounds to 2000 pounds, the average being about 1600 pounds. The circulating roll is raised or lowered by means of a worm gear, in order to vary the slight brushing action that the stock receives. By installing a bed plate and using sharper knives, these washers can be readily converted into beating engines. The octagonal-drum washing cylinders are constructed on the usual bucket arrangement pattern. The faces of the cylinders are first covered with $\frac{1}{4}$-inch mesh facing wire, and are topped with 60- or 70-mesh washer wire. It has been the custom heretofore only to use old Fourdrinier machine wire for facing the cylinder; but experiment has proved that a larger screening surface is obtained by using the larger $\frac{1}{4}$-inch mesh wire for facing and covering this with wire that has been woven especially for the washing of stock. Nickelalloy 60-mesh wires have been placed on the washing drums; and, after $1\frac{1}{2}$ years of service, they have shown no perceptible wear. They do not require any scouring out with acid, and, barring accident from puncture, they should have a much longer life than this. The cylinders are equipped with a raising and lowering ratchet wheel.

105. Operations.—After being thoroughly cooked, the papers are furnished to the washers, either from the chest C, Fig. 15, or as described in Art. **81.** Sometimes 2 or 3 quarts of kerosene is added; this keeps down the froth and foam that will otherwise result when the saponification products (soaps) of the cooking process, which have been absorbed by the papers, come in contact with the washing cylinders and the rapidly revolving circulating roll. When the washer has been completely furnished, the washing cylinders are lowered and the wash water is turned on. The amount of water used is regulated to correspond to the volume removed by the cylinders; thus a continuous stream of fresh, clear water is being added to compensate for the water removed, which is laden with the soluble saponification products, ink and dirt particles.

In this type of machine, the fresh water is admitted to the stock, sometimes at the bottom of the washer and in back of the roll, through a 6-inch pipe. This water dilutes the stock, passes up through it and out by the revolving cylinders, and goes to waste. Sometimes the water is introduced in front of the roll, which mixes it with the stock. It is a slow process of constant dilution of the impurities of the cooking action, and a large

volume of wash water is required. This same volume of wash water, if applied to the stock in batches of equal amounts and then removed, thickening the stock after each addition of fresh water, would greatly lessen the time of washing and would produce a cleaner pulp.

106. Removal of Dirt.—By the constant dilution of the dirt, the amount of dirt remaining in the pulp is gradually lessened. This progressive action continues indefinitely; but, even after the stated washing period has expired, the stock still contains dirt, though, of course, only a very small amount. If at this point, a sample of stock be taken from the washer and subjected to a stream of fresh water on a small hand screen, the stock will brighten up at once to a snow-white color. It is this principle that has been taken advantage of in the modern continuous washer.

107. Removal of Carbon of Inks.—If the paper stock has been thoroughly cooked, the carbon of the inks is readily removed. In the open-tank process, the papers still retain, largely, their original flat shape after cooking; hence, on immersing a sheet of cooked paper in water, the individual letters of solid carbon can be loosened from the paper by gently moving the sheet to and fro. The same result is obtained in the cooking engine by the action of the roll on the papers, the friction of the papers against the sides and bottom of the tub, and against the cylinders; the continual rubbing and friction in the mass also further the removal of the inks and the formation of an emulsion, which is readily removed in the wash water.

For the first hour of washing, the wash water is very muddy and dirty. Continued washing clears the stock; and the color gradually changes from the heavy gray tone to a blue white, for ledger stock, or to a cream white or ocher tint, for book or magazine stock.

108. Duration of, and Effect of, Washing.—The time required for a thorough washing depends on a number of factors. The degree of cooking that the paper has received must first be considered. If well cooked, the inks will readily emulsify with the water; but if the paper has not been completely cooked, the ink still sticks, or perhaps it may loosen from the surface of the paper and be found later in the finished paper. If the papers are dry cooked, no amount of washing will clear the ink from the

pulp; and after being bleached, this product has a light grayish tone, similar to the color of newspapers.

109. The second factor to be considered is the nature of the printing inks. It has been found that ordinary book and magazine inks and colors are easily washed out; but lithograph and label papers that contain waterproof inks and varnishes, present greater difficulties. Solid ledger papers are easily washed out; they have received a harder treatment in cooking to dissolve the hard sizing, the inks readily emulsify, and a clear, blue-white pulp is obtained with about $2\frac{1}{2}$ hours of washing, $\frac{1}{2}$ hour for bleaching, and $\frac{1}{2}$ to 1 hour for removing bleach residues.

110. The third factor to receive consideration is the composition of the papers to be washed. Long-fibered stock, such as writing and ledgers, require a much shorter washing period than
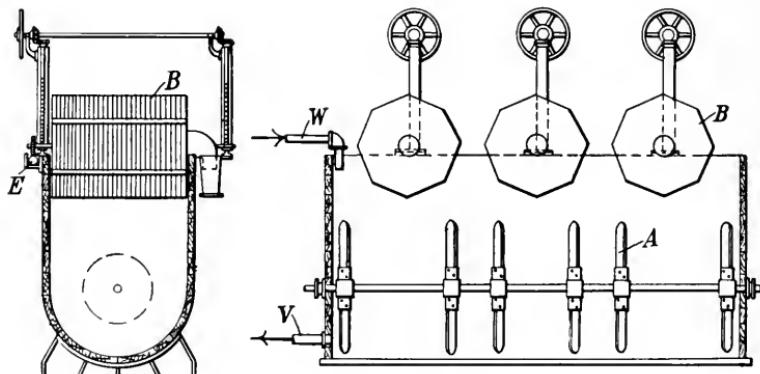
Fig. 18.

the short-fibered book stock. The fourth factor is the circulation of the stuff in the washer and the amount of water used, which influences the washing period. The third and fourth factors are really dependent on each other, for the larger the volume of water the faster the stuff will circulate, and the larger the volume of water used the greater will be the amount of dirt and ink removed in a shorter period.

111. When the paper stock is considered to have been washed long enough, a sample of the wash water is taken out and examined. If the water is clear, the pulp is ready for bleaching; but if the water is still cloudy, if a grayish sediment is noticed, the washing must continue until clear fresh water is obtained.

The first washing will generally take from 3 to $3\frac{1}{2}$ hours for the usual run of paper stock, such as book and magazine.

Before bleaching, it is well to concentrate the stock by shutting off the water, but letting the cylinders run for a time.

112. Other Forms of Washers.—In Fig. 18, is shown a machine that both washes and concentrates. The agitators A keep the stock well mixed, and the rotating dippers B, which are covered with wire mesh (60 mesh over 14 mesh), take out the dirty water as fresh water is added at W. On shutting off the fresh water, the stock is concentrated, thus saving bleach and storage space. This washer handles 1500 pounds of waste-paper stock at 3% to 4% in from 2 to 3 hours; it requires about 6 h.p. to operate it. Each washing cylinder B is driven at 8 r.p.m. by a worm gear from a shaft E. The washed stock is removed at V.

113. Another type of washer, which is meeting with some favor, is a slightly inclined, slowly rotating cylinder C of fine wire cloth, shown in Fig. 19.
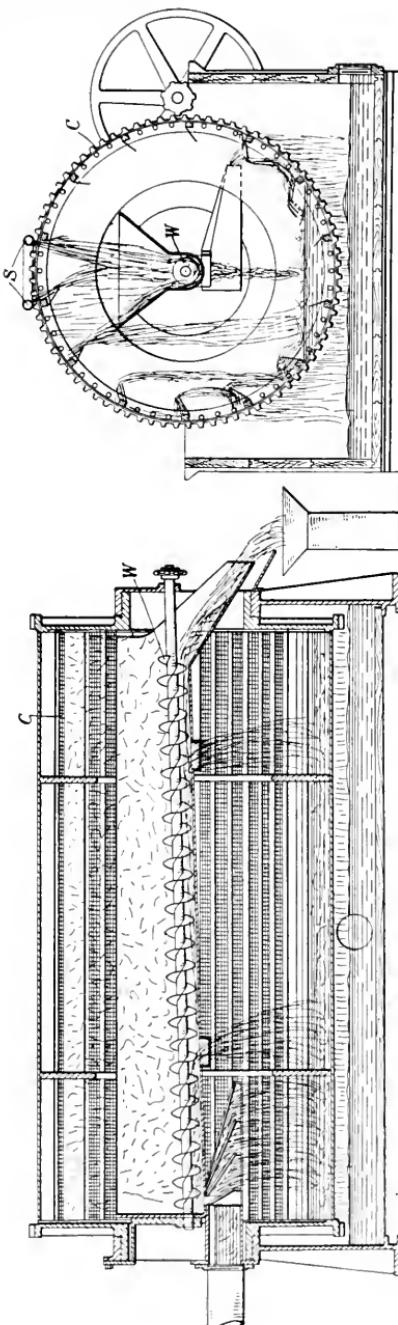
Fig. 19.

The stock is fed in at one end and is distributed by worm W; and as the dirty water drains out, the fibers are washed with showers, S, finally emerging at the other end.   Very little power is required to operate either of the washers just described; but practical men consider them to be wasteful of stock.

114. A new type of washer, which is giving good results, is shown in Fig. 20; this washer is very effective for washing thick stock rapidly.   It is better to wash stock when it is thick, if the water
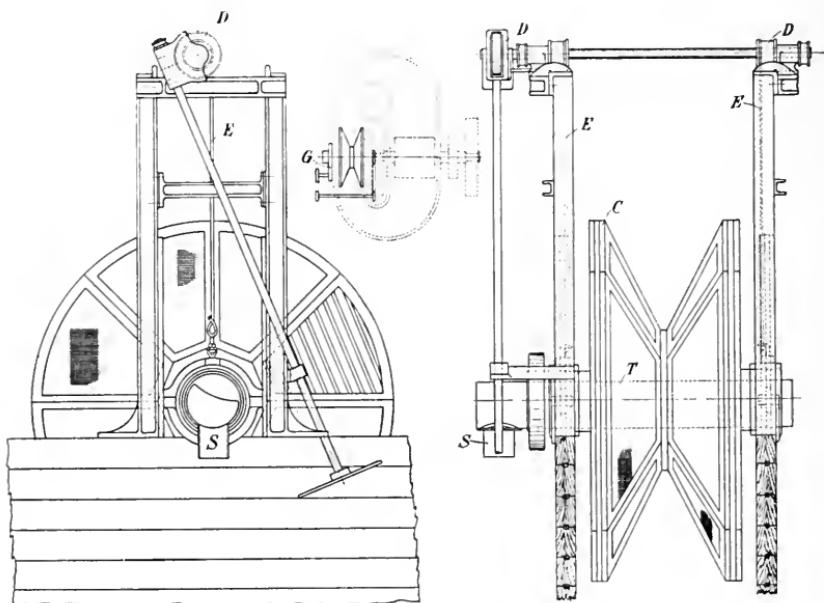
Fig. 20.

can be removed; because, first, there is less stock lost, and, second, on account of the small amount of water in the stock, a given quantity of water added or removed produces a greater effect. S (Fig. 20) is a spout through which dirty water is discharged from the hollow shaft T at the center of the cylinder C; D is a worm gear for lifting the washing cylinder by means of cables E. This washer was developed as a feature of the beater shown in Fig. 3, which is also used as a washer and bleacher; it circulates stock of unusually high consistency.   The small view shows the assembled washer, in which G is the gear, belt driven from the beater-roll shaft.

(a)

(b)

Fig. 21.
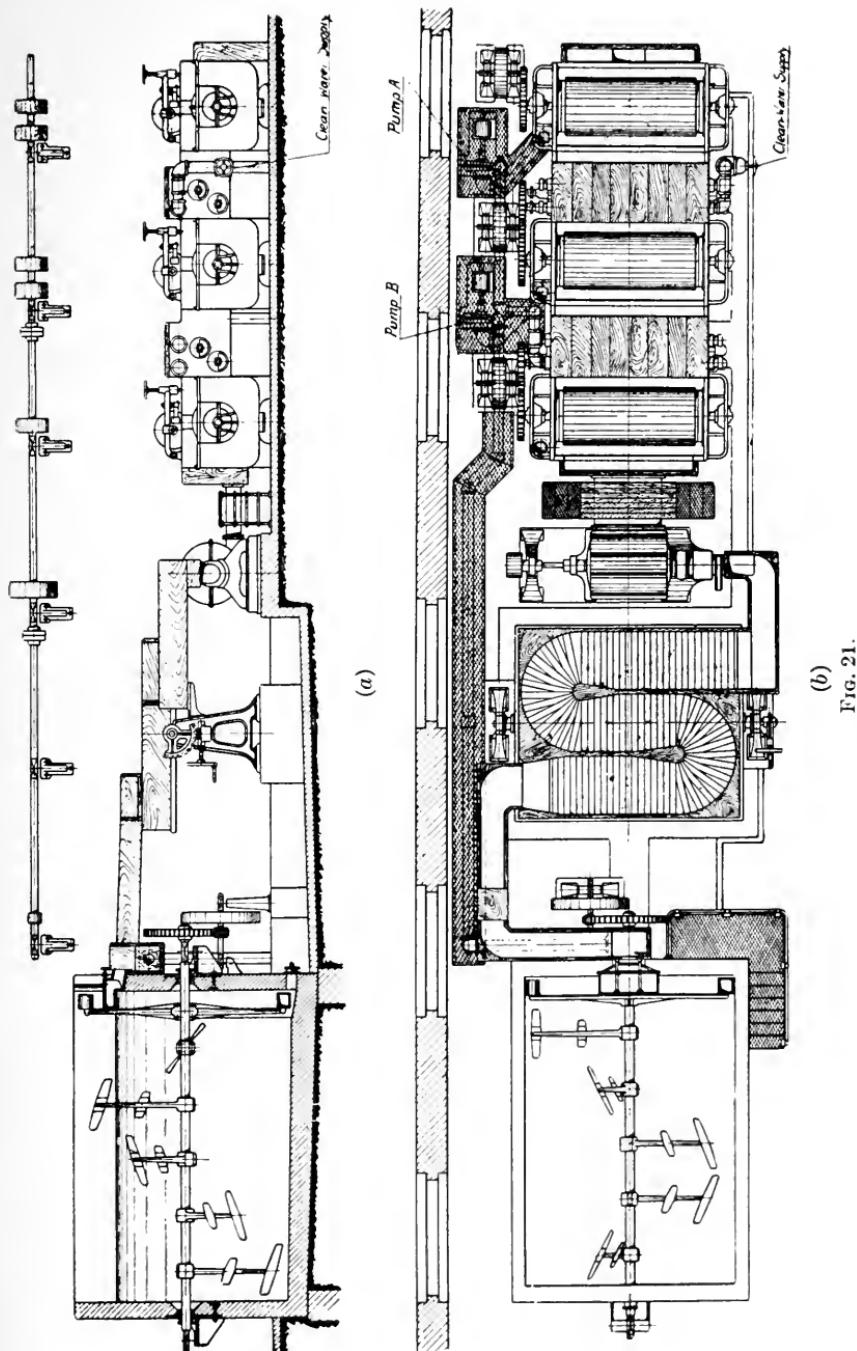
115. A Three-cylinder Washer.—The tendency to take advantage of a continuous process has become well-marked in waste-paper recovery; and much attention has been given to the three-cylinder washer, which authorities regard as the ideal type of washing machine.

An improved washing system for removing ink from cooked waste papers is shown in Fig. 21, (*a*) being a side view and (*b*) a top view. The arrangement consists of a horizontal stuff chest, from which the stock is lifted at a uniform rate by means of a bucket wheel; a gravitator (or sand trap), the feed to which is controlled by a gate; a centrifugal screen, for removing the dirt not caught in the gravitator; and a washing machine, which comprises three cylinder units. The cylinder in each unit picks up a layer of stock in the same manner as a pulp thickener, and delivers it to a couch roll, from which it is scraped and passed to the next unit.

The water consumption is small, by reason of the economical way in which the water is handled, and 80% to 90% of the ink is removed in the first cylinder; this water is not again used for washing. The water from the second cylinder is pumped to the stuff chest by pump *B*, where it is used for thinning the stock delivered by the buckets. The water from the third cylinder, which is, of course, the cleanest, is pumped into the first agitating trough by pump *A*, and is there used as thinning water. The only place where clean fresh water is used is in the final washing operation, which occurs in the last agitating trough.

BLEACHING THE STOCK

116. Consumption of Bleach.—After washing, the recovered pulp is ready to be bleached. For a washing engine of 1600 pounds capacity, about 60 to 70 gallons of bleach liquor is used for book and magazine stock. The liquor should test 6°Tw. at 60°F., which is equivalent to about $\frac{1}{2}$ pound of bleaching powder to a gallon of liquor; this amounts to 2 to 3 pounds of powder to 100 pounds of dry papers. This volume of bleach liquor is allowed to act, without heating the pulp, for 30 to 45 minutes, and it should produce a snow-white pulp. By taking the chill off the water and raising the temperature to about 80° or 90°F. (never higher than this), the bleaching operation may be greatly shortened. It has been found by trial that a warm bleaching of 15 or 20 minutes

duration produces very efficient results. It has also been demonstrated that, when necessary,—such an occasion arose during the World War,—a good bleached pulp can be produced with 0.6 pounds of bleaching powder per 100 pounds of papers; this amount, however, did not give the product the white tone that may be obtained with a larger consumption.

After giving the bleach sufficient time to act, fresh water is turned in, the cylinders are lowered, and the bleach residues are completely washed out. To test for the complete extraction of the bleach, the well-known test of starch and potassium iodide is applied; any chlorine that may be present will be revealed by a distinct blue tint.

117. Bleaching Stock from Special Papers.—For bleaching ledger stock, about 35 to 40 gallons of bleach solution for 10,000 pounds of paper is required, depending on the quality of the paper. A thoroughly washed, solid ledger stock presents a fine blue-white appearance, even before the introduction of the bleach solution. The mixed ledger, which consists of letterheads, invoices, bills, letters, and other similar papers, presents a motley array of colors, and it requires a thorough bleaching; but, even then, the resulting pulp has a faint tone, dependent on the proportion of the strongest colored stock present. However, with the exception of the heavier mineral colors, such as chrome-yellows, oranges, greens, umbers, and ochers, the colors are easily removed with 40 to 50 gallons of bleach liquor. The bleaching of this grade of stock requires from 45 to 60 minutes to obtain the best results.

118. Variation in Color of Bleached Pulp.—It is quite impossible to obtain a strictly uniform color in the bleached paper stock. There is such a wide variation in the composition of the papers treated, in the many different colors present, and the variation in the degree of cooking in different parts of the open tanks, that this difference is to be expected. A simple expedient, used in many mills to obtain a good sample for matching pulp from beater to beater, is the following: A sample of pulp is taken from the beater and pressed with the hands into a ball, about the size of a baseball. With practice, it is very simple so to press all the sample balls that each will have very nearly the same percentage of moisture. By breaking a ball into halves and comparing one half with a half from another ball, a good idea of the variation between the two may be obtained. (When com-

paring two pulps, it is very important that both have the same moisture content.)   These balls can be stored on a shelf, marked with the beater number and the time, and can then be inspected later by the superintendent and foreman, if this is desired.

It is the practice in one mill to dump the bleached stock, together with the bleached residues, into tanks, from whence it is pumped up over the screens and back to the drainers (see Fig. 15, Section 1), where the stock is allowed to remain until all the surplus liquor drains away and the drainer is filled.   In this way, the bleach residues have an opportunity to become dissipated while oxidizing any organic coloring matter that may still remain in the stock.   The door to the drainer is then opened, the pulp is forked into cars or containers, and is furnished to the beaters.   When taking stock out of the drainers, it is removed in vertical sections, so that the various tinted strata of stock may be kept uniform in all the beaters furnished.   In this way, it is simple to keep the shade of the finished paper constant.   If the pulp is put into the drainer hot, the color will surely deteriorate.   It is best to wash the pulp in the bleacher.

119. Use of Wet Machine.—Another method in vogue is to run the washed, bleached, and screened stock over a wet machine (fully described in Section 1) and into laps of pulp of about 25% to 30% air-dry fiber; the laps are stored according to the grade of paper and the resultant shade.   This method of handling screened pulp possesses many advantages, and was adopted by one of the most modern book-paper mills; it is considered to be the most economical and efficient method in use, for the following reasons: No elaborate pumping systems or storage tanks are required; the loss of time in furnishing the beaters with diluted pulp is eliminated; the wet machine can be run independently of the grade of stock being used; the storage of the pulp ahead of the beaters, and the possibility of an immediate change from one grade of paper stock to another, is a wonderful saving and improvement; the ease and exactness with which the color or shade of the paper made on the machine is maintained.

SHRINKAGE OF COOKED PAPERS ON WASHING

120. Amount of Shrinkage.—The shrinkage of paper stock on washing has always been a stumbling block for many mills that have considered the adoption of cooked paper stock for a part of

their pulp requirements. The exact per cent of shrinkage has, perhaps, never been worked out under actual mill-working conditions; but it has been estimated to range from 20% to 40%. If the paper treated is all coated paper, practically all the coating is removed by the de-fibering and washing of the stock, and a shrinkage of 40% will probably result, but this does not include the loss of any filler that may be present in the raw stock before the coating was applied, which amounts to 5% to 8% additional. Toward the end of the washing process, that is, when the wash liquor is free from dirt and contains only short fibers, it is usually considered that an additional loss of 1% occurs for every added 15 minutes of washing. Therefore, it is not advisable to wash any longer than is necessary to get standard color.

Machine-made paper has usually received a thorough beating or refining treatment. The individual fibers have been drawn out and cut up in the beaters, and the refining engine again reduces the length of the fibers, when necessary. Then, too, bleached soda pulp is quite generally used, much of which consists of fine or short fibers. There is no way of preventing the loss of most of this fine-filling fiber, if the stock is thoroughly de-fibered and washed through the 70-mesh washing cylinder wire.

121. Limits of Shrinkage.—Numerous ash tests have been made on the completely washed and bleached paper stock, and the results vary from 2.5% to 4% total ash. When this percentage is compared with the coating ingredients of paper, which amount to from 30% to 40% of the weight of the paper, the shrinkage is well nigh startling.

Books and magazines are usually printed on supercalendered paper, which contains 15% to 20% ash. The loss in ash alone (not reckoning the 20% of bleached soda fiber that is usually present) thus varies from 15%–20% to 2.5%–4% which shows, perhaps, the lowest minimum shrinkage. In solid ledger stock, the shrinkage is largely equivalent to the loss of the heavy sizing,—both animal and rosin sizing,—because the stock is usually 80% to 100% rags, which have a long fiber. The remainder of the fiber composition is long-fiber sulphite, which does not entail a great loss.

It is safe to say that the average loss in washing of all kinds of paper, well mixed, will be 20% to 30%.

SCREENING WASHED AND BLEACHED PAPER STOCK

122. Importance of Screening.—After the old paper stock has been washed, bleached, and dumped into storage tanks, it is ready to be screened, which is the fourth very important step in the treatment of waste papers, although it is an almost forgotten detail in some mills.

123. Common Form of Screen.—The usual screening system in American mills is exceedingly simple and is frequently inadequate. One flat diaphragm screen of six plates, each plate 12 inches wide and 40 inches long, is considered sufficient to screen stock for three beaters of 1000 pounds capacity. About 3.5 h.p. is required to drive a screen of this type. The stock is pumped up from the storage tanks, at a consistency of about 3.5 ounces per gallon (equivalent to 2.66%), onto sand traps. (For disinfection of scums, see Section 7, Vol. III, and Section 6, Vol. IV, under white water.)

124. Sand Traps.—A common sand trap is 24 inches wide, 30 to 40 feet long, and 12 inches deep; it is placed 8 to 10 feet above the beater-room floor, thus allowing free passage underneath. The bottom of the sand trap is lined with canvass, such as old cotton dryer felt from the paper machine, or is fitted with cross dams.

The purpose of these long narrow boxes, or sand traps, is to permit the heavier particles of impurities in the washed stock to settle out and collect on the rough surface of the dryer felt, or behind the dams. The efficiency of the sand traps is dependent on the dilution of the stock, the rate of flow over the course, and the length of the course. The depth of the stock is about 8 inches, the slope of the course is about $\frac{1}{2}$ inch per foot of length, and longer the length of the course the more impurities will settle the down.

The impurities found in these traps are mostly pins and clips, such as are attached to letters, staples and fasteners from book backs, rubber bands, bits of rags and strings, sand and heavy pieces of grit. A film of fine particles of iron rust is found to be covering most of the dryer felt bottom.

125. Furnishing the Beaters.—From the sand trap, the stock may go back to the chest, or through the screen and to the beater or wet machine. When the beaters are ready to be furnished, the gate to the screens is opened, and the stock from the sand trap

flows onto the screen.   Here it is diluted with water, to separate
fibers from impurities, and to enable the stock to be screened
without clogging the slots and flooding the entire screening
surface.   If the latter should occur, an overflow is arranged to
take care of the stock, and this overflow returns the stock to the
storage tanks.

In most of these single screens, three (3) plates are cut 0.010
inch and the other three 0.016 inch, or thereabouts.   The density
of the diluted stock as it is furnished to the beater is equivalent to
1.27% furnish; this means that 1 pound of dry stock is diluted
with 9.44 gallons of water, since $1 \div (9.44 \times 8\frac{1}{3}) = 0.0127$
$= 1.27\%$.   To furnish 600 pounds of dry stock at this dilution,
the washing cylinders in the beaters must remove 600×9.44
$= 5664$ gallons of water, which requires from 45 minutes to 1 hour.

Since 99% of the fine dirt particles have a diameter smaller than
0.016 inch, they have free passage through this size of openings in
the screen.   The paper made from this screened stock is sprinkled
with fine dirt particles, and the quality of the product is thereby
lowered.

126. Effect of Poor Screening.—By far the largest percentage of
the materials retained on the screens consists of small bits and
particles of broke or paper, which have not been completely
de-fibered in the washing engine.   The amount of this material in
the screenings has startled many mill superintendents; but,
instead of remedying the trouble, they have side-stepped it by
increasing the size of the screen cuts, in some instances up to
0.028 inch.   This, of course, cuts down the amount of screened
undefibered stock somewhat.   An attempt is made to clear or
finish the de-fibering of this stock in the beater and, later,
by refining it shorter in the Jordan engine.   This method may
work part of the time; but, occasionally, the increased production
of the paper machine calls for more stock, in which case, the
beaters are crowded and cannot condition the stock in the same
degree.   Then, too, when the stock is run long, that is, when a
good strong-fibered sheet is required, very little beating is
necessary, except to clear the sulphite or soda pulps used, and the
Jordan engine action is reduced almost to a bare clearing of the
stock.   The result is that the finished sheet is sprinkled with
these particles of undefibered stock of varying size.   At times,
they are so much in evidence that they are the cause of the sheet
breaking down at the wet presses, and offer untold difficulties in

carrying the sheet over to the calenders, besides being a means of carrying ink particles into the paper. The reason for this breaking down is explained by the fact that the particles of broke have no felting power, and whenever they are present, they produce a weakened spot in the sheet. On going through the calenders, these are made transparent, and they stand out quite distinctly in the finished sheet. This defect in the finished paper, especially in coated paper, results in sheets of lower quality, or seconds. .

QUESTIONS

(1) What factors influence the rate and completeness of washing old paper stock?

(2) About how much bleaching powder is required to bleach, in pulp form, 100 lb. of dry papers?

(3) What is your opinion of the suggestion to use a wet machine in the handling of cooked waste paper stock?

(4) What kind of equipment is used in screening waste paper stock? Explain the importance of this operation.

TREATMENT OF WASTE PAPERS

EXAMINATION QUESTIONS

(1) Mention some reasons for the extensive use of waste papers.

(2) (*a*) What chemical action takes place in the removal of printing ink? (*b*) What kind of chemical is used?

(3) What are the four principal classes of waste papers?

(4) Name the principal operations in treating waste papers for paper making.

(5) Describe, with sketch, one type of waste-paper duster, and tell how it works.

(6) What becomes of the discards from the sorting room?

(7) Explain the term dry cook and the result of a dry cook.

(8) If you were planning a mill, would you consider the recovery of soda-ash liquor an important factor? Give reasons for your answer.

(9) (*a*) What are the three principal factors in cooking? (*b*) how does a change in one affect the other two?

(10) What influence would the cost of power exert in connection with the selection of the cooking-engine process?

(11) (*a*) If the consistency of a 900-lb. batch of papers being cooked is 5%, what is the total weight of the charge? (*b*) How much of the charge is water, allowing for the soda ash found in (*a*)?

$$\text{Ans. } \begin{cases} 18,000 \text{ lb.} \\ 17,055 \text{ lb.} \end{cases}$$

(12) Taking 1 B.t.u. as the heat required to raise the temperature of 1 lb. of water 1°F., and assuming paper and soda ash to have the same specific heat as water, how many heat units will be required to raise the temperature of a batch containing 900 lb. of paper and chemical, at 5% consistency, from 45° to 175°F.? Ans. 2,340,000 B.t.u.

(13) What test shows when bleach residues have been washed out of the stock?

(14) (*a*) Give maximum, minimum, and average losses in washing old paper stock.   (*b*) Mention some sources of these losses.

(15) (*a*) Which method of cooking old waste papers is most popular?   (*b*) Which method do you consider best?   Give reasons.

SECTION 3
BEATING AND REFINING

By Arthur B. Green, A.B., S.B.

with Bibliography

By C. J. West, Ph.D.

INTRODUCTION

1. The Preparation and Supply of Stock for the Paper Machine.
The two operations of **beating and refining** also accomplish the
necessary mixing of the various materials that are to go into
the final paper, and also the necessary reduction of the pulps, or
fibrous materials, to such a state that they will form themselves
into a sheet of the desired characteristics. As for the many
classes of pulps, the sources from which they are derived, the
processes by which they are extracted from nature, and the
processes by which they are purified and whitened, these have
already been dealt with in preceding sections. These processes
fit the different pulps in various ways for the operation of beating.
They may or may not be carried on in the same works, or under
the same management, as the beating and refining themselves;
but wherever beating and refining are carried on, they represent
the first step in the actual making of paper, and are always
included in the same works, and under the same management, as
the paper machines, which transform pulp into paper.

Beating and refining are different processes. Where they are
both carried on, however, they are for the same purpose, and
constitute two successive steps in the preparation of the stock
for the paper machine. Refining is not always done; but, with

§3   1

very few exceptions indeed, there is always something in the nature of beating as the first step in making paper from pulp. In some grades of paper, the amount of beating required is so slight that the process has degenerated from a highly skilled operation to hardly more than proportioning and mixing, carried out almost automatically. Newsprint is one of these grades, and great tonnage of paper is made every day with no more beating than this. Nevertheless, in higher, more expensive, grades of paper, it is the beating that largely determines the quality and value of the final product.

2. Beating Defined.—**Beating** is a general term for the mechanical treatment given to paper-making materials suspended in water, to mix them and to prepare them for forming on the paper machine a paper of the desired character. **Refining** is a further mechanical treatment, which usually follows the beating or mixing, to complete the preparation of the materials.

The beater and the refiner are different pieces of equipment. There is usually more than one beater for one paper machine, the several beaters being furnished and dumped in rotation, all discharging to a common chest on the floor below. Thus beating is done in batches, and comes under the class of processes known as "batch" processes. The chest on the lower floor serves as a reservoir from which the beaten stock is pumped up to the refiner in one continuous stream, and thus it passes continuously through the refiner. Refining falls under the class known as "continuous" processes. There may be one refiner for one paper machine, or there may be several; in the latter case, they may work in parallel for capacity, or in series for maximum action on the fiber.

It is at the beater that the materials which are to impart to the final paper its color, opacity, sizing, etc. are added to the fibrous pulps. These materials are not pulps; they are non-fibrous. Their action and their effect is partly physical and partly chemical.

3. History of Beating.—Not all of the facts are known that would be necessary to fix the exact time and place of the first use of beating. The very early papers made in China were fashioned from fibers of the inner bark of certain trees; and the nature of these fibers allowed of enmeshing them into a sheet without beating, so long as the work was done by hand and the

uses of paper were confined to such qualities as could be produced in this way. In the eighth century, the art spread from the Chinese to the Arabs, then from the Arabs to the Greeks and Moors, and reached Europe in the thirteenth century, by which time, rags had become so general as raw material for paper as to make it certain that some beating must have been done before the fibers were ready for the hand mold.

The early process for reducing cotton rags to pulp consisted first of rotting, next washing in open streams in bags, and finally pounding, either with mortar and pestle, or on stone surfaces with hard wooden implements. The pounding was hand labor; but before the eighteenth century, machinery was devised for doing the pounding; that is, heavy wooden stampers were fitted to a row of upright cylinders, or pans, made of wood or stone, and by means of trippers attached to a shaft driven by a water-wheel these stampers were raised and allowed to fall. This was known as the stamping mill.

These stampers were divided into three groups: The first group were shod with heavy iron teeth or nails, to tear the rags; the second group were shod with finer teeth to draw out the fibers; and the third group were of hard wood, weighted but not shod, and served to bruise the fibers. Fresh running water in the first two groups of pans washed the rags through holes in the bottom, covered with fine hair-cloth. It is said that this process of beating took about 32 hours, and that a mill with six pans could produce about 500 pounds a week. Fibers treated by these early processes went into the paper very much greater in length than is the case with any grades of modern paper; and the sheets that have been preserved from early times show remarkable strength.

4. Invention of the Hollander.—About the middle of the eighteenth century one of the great steps was taken in the advancement of the paper-making art when the Hollander beater was developed in Holland to replace the stamping mill. It was claimed that two beaters could be run by the power required for one set of stamps. Instead of the row of cylinders or pans, there was an open tub, roughly oblong, with ends rounded, and with a partition in the center, built parallel with the straight sides, allowing continuous flow of the pulp along one side, around the end, along the other side, and around the other end. On one side of the partition, a roll was mounted on a heavy spindle,

which extended across the tub at right angles with the long side. Under the roll was built a suitable bed-plate; and both roll and bed-plate were fitted with bars of metal. Near the roll, on the side turning upward, was built a back-fall, over which the roll would throw the pulp, and over the roll was a hood to confine the splash. Thus, as the roll was turned rapidly in close bearing upon the bed-plate, the pulp was propelled around the open tub, and passed repeatedly under the roll. The Hollander is the type of beater in common use today; and in principle it has not been changed since its invention, nearly two hundred years ago.

BEATER CONSTRUCTION AND OPERATION

TYPES OF BEATERS

5. General Considerations.—Although beating, as a necessary means of preparation of the stuff, has been in use for three centuries or more, nevertheless it is not yet possible to state accurately what the beater accomplishes. Brushing, cutting, bruising, brooming, hydrating, attrition, are among the terms used to describe what happens to the fiber in the course of beater treatment, but these are general terms, and it is impossible to say how many of them apply to the beating of any particular kind of stuff,[1] or in what proportions these various actions take place. This phase of the subject will have further treatment in later parts of this Section, under the heading Theory of Beating; but in considering the various designs of beating equipment now to be described, it should be born in mind that none of them can be said to be based on accurate knowledge of the beating action.

The different types of beaters are described roughly in the order of the extent to which they are used. The first, the Holländer, now generally written Hollander, is by far the most prevalent.

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[1] **Stuff** is the name given to fibrous paper-making materials after mixture with whatever non-fibrous substances are used and after beating and refining, ready for the paper machine. These materials are in suspension in water. The milky mixture flowing out on the paper machine is also called stuff, but in this book it will be called **stock**. It has been modified from the beaten and refined state only by dilution with water and with back-water from the machine. Pulps ready to furnish to the beater, particularly in fine paper mills, are called **half-stuff**.

THE HOLLANDER

6. The Hollander Tub.—The **tub** of the Hollander consists of an open vessel, built usually of wood or cast iron, the wooden construction being shown at A, Fig. 1. The rounded ends of
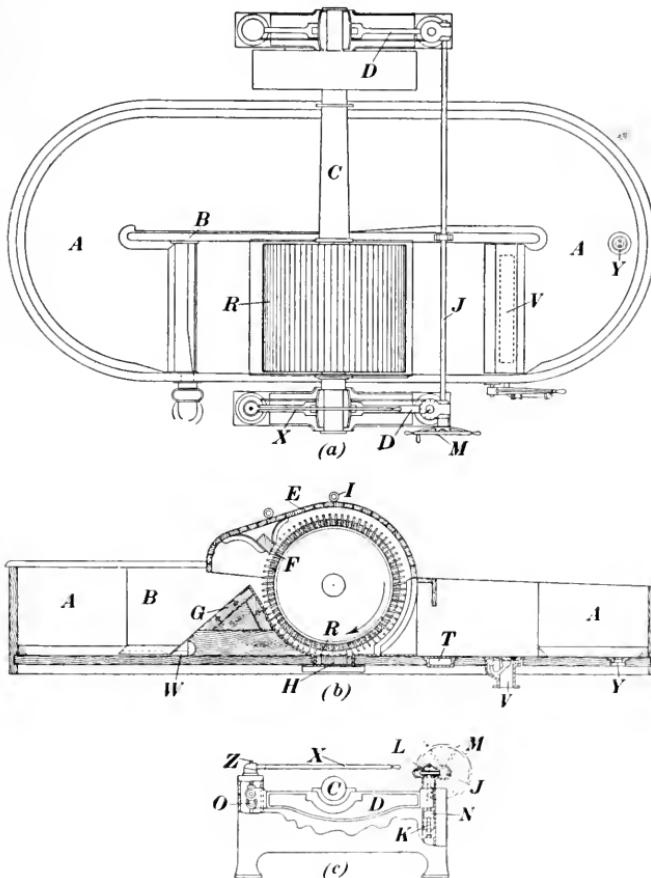
Fig. 1.

the tub, in conjunction with the central partition B, called the **midfeather,** or *midboard*, form the channel through which the stock travels in continuous circuit. In later types, the tub has been made of concrete, though this has been used more often where the design of the tub is more complex, that is, in other designs of beaters. The cast-iron tub is best adapted where heat is used in the beater to assist in disintegrating old-paper stock, as in board mills. In mills making fine papers, where color and

cleanliness are prime requirements, beater tubs are lined with sheet copper and beater bars and bed-plate knives are made of a non-corroding metal such as bronze. A Hollander . beater measuring approximately 20 feet long and 9 feet wide, with sides about 3 feet 6 inches high, will hold approximately 1350 pounds of air-dry stock at a consistency of about 5%.

An integral part of the beater tub is the **back-fall** G, shaped on one side to conform to the curve of the beater roll, and having on the other side a steep slope. The roll throws the stuff over its crest, thus forming a head, so that the force of gravity causes the stuff to travel away from the roll, around the tub, and thus back to the roll again. This travel is called *circulation*, and stuff circulating in the beater tub is said to *turn*. Due partly to the use of short-fibered stocks in recent years, the design of the tub and back-fall is receiving considerable study, and many modifications are now offered, without departing from the Hollander type, to secure more rapid circulation and beating.

7. In some beaters, as an aid in dumping the stock, water may be introduced at the base of the back-fall, as shown at W. For certain kinds of stock, especially with rag half-stuff, the beater is equipped with a narrow metal box T, Fig. 1 (b), set in the floor and covered with a perforated plate. This acts as a trap for heavy particles of metal, dirt, or sand, and is called a **sand trap.** It is cleaned through a small opening to the sewer or by hand. Valve Y is a sewer connection for cleaning out the tub, and V is a valve for emptying, or dumping, the beaten stock to the chest. In most cases, these valves consist essentially of a heavy metal plate or disk, fitting into the opening with a ground joint. In some recent designs, the dumping valve may extend from the front side to the midfeather and be so designed that, when the cover is raised, it acts as a baffle to deflect the stock to the opening.

In Fig. 1 (b), it will be noticed that the bottom of the tub is flat, and that there is only a small fillet around the bottom of the tub and midfeather where it is joined to the sides of the tub. An increased speed of circulation and a higher concentration or density (consistency) of stock are rendered possible by raising the bottom of the back-fall at W higher than the bottom of the tub at Y or T, thus permitting a gentle slope for the stock. Lodging of inert or dead stock in the corners can be avoided by having the bottom of the tub U shaped, as can be readily done with concrete construction.

8. Beater Roll and Bars.—A heavy spindle C is mounted across the tub at right angles to the midfeather, and is supported in bearings at its ends, the bearings resting in lighter bars D. To this spindle is firmly attached the beater roll R, usually called the **roll.** The spindle and roll are revolved by means of a belt or chain drive from a constant speed shaft or motor to a large pulley on the back side of the tub. This pulley may be either inside or outside the back-side lighter bar.

9. The typical beater roll is built on three or more cast-iron spiders A, Fig. 2, which are keyed to the roll spindle B. The spiders are slotted to receive the **fly bars** C. These bars are
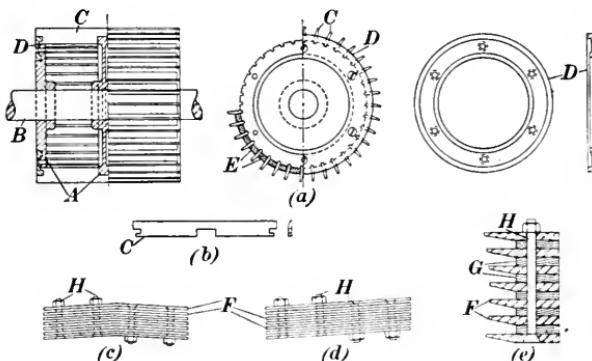
Fig. 2.

themselves slotted at both ends, as shown in detail at (b), for the hoop or band D by which the bars are usually held in place and kept from flying off at a tangent. The bars may be evenly spaced or set in clusters, the arrangement and number varying with the kind of stock to be beaten and the kind of paper to be made. Wooden blocks E, cut slightly wedge shape, and called *filling*, are driven tightly between the bars. This filling is made from dry, well-seasoned, hard wood; and the water in the tub produces a swelling of the wood, which tends to hold the bars fast and prevent vibration. There are, however, several methods of fastening the bars C to the spiders A. In one case, the bar is dropped into a notch in each spider, and is fastened in place by drilling a hole in the bar over a pin or lug in the side of the notch, the bar being firmly held by pouring in a low melting alloy, or by screwing down a wedge. In other cases, the bars are held in place by a circular plate or hoop D, which is firmly bolted to the outside spiders, and by a driven fit in the slots of the spiders.

The beater roll R, Fig. 1, is so designed that its width (face) nearly fills the space between one side of the beater tub and the midfeather. It may weigh, together with the spindle and pulley, from 3000 to 6000 pounds and may be revolved at a peripheral speed of from 1500 to 2500 feet per minute. The width and diameter of the roll depend upon the dimensions of the beater.

10. In most cases, the beater-roll bars are made of metal; steel is in most common use, though bronze, manganese bronze, phosphor bronze and manganese steel are also used. A new design provides a cylindrical shell with the bars on the outside and spiders inside, all cast in one piece, and the bar edges turned true. Since different kinds of stock need different beating treatment, it is necessary to consider the quality of the bars for the particular stock to be beaten. For certain papers where the stock has to be beaten very "wet," such as glassine, or where the paper must be free from metal particles, such as sensitizing paper and condenser paper, a stone roll is of value, because iron causes rust spots, discoloration of tints, etc. This latter type of roll is usually made of basalt lava or a mixture of concrete and quartz, and may be built up by using narrow blocks that are held to the spiders by pins or bolts. Blocks of porous cast iron may be employed in the same way. It is possible, however, for a roll to be cut out of a block of basalt lava, or to be built up with concrete and flint on an old roll, by removing some of the bars and using the others for a bond.

11. In order to prevent loss of the stock that is carried around between the bars of the roll, a covering E, called a **hood** or **curb,** is placed over the roll. This, in part, conforms to the shape of the roll and extends back and down the sides, and is firmly bolted to the sides of the beater tub. To facilitate the circulation of the stock and to prevent if from being carried over the top of the roll, a baffle F is attached to the curb to deflect the stock over the back-fall. The design of the curb and baffle is of great importance, as will be brought out later.

12. The Bed-Plate.—Directly beneath the roll is the **bed-plate** H, Fig. 1, frequently called the **plate**; it is set in a chair or box by means of wooden wedges accurately parallel to the axis of the roll. The bed-plate, Fig. 2 (c) and (d), is made up of strips of metal or bars F, set on edge, spaced with wood filling G, and firmly bolted together at H. This is shown in large detail at (e).

These plates may be elbow plates, as shown at (c), or may be straight, as shown at (d), and set at a slight angle to the axis of the roll, or may take one of numerous other forms. The plate and plate box, or *chair*, are so designed that the plate may be removed through an opening in the side of the beater when necessary, by removing a bolted cover plate.

13. The Roll-adjusting Mechanism.—In the operation of the beater, the only adjustment made after beating begins is the raising or lowering of the roll; the mechanism for accomplishing this is shown in detail at (c), Fig. 1. The lighter-bar D is pivoted at one end at O; the other end rests on a nut N that runs on a vertical threaded rod K, between guides in the lighter stand, which keep the nut from turning. At the upper end of the rod K is a worm gear L; this engages with a worm on the shaft J, which extends across both lighter stands, and is turned by means of the wheel M. In this manner, a very minute vertical adjustment is given to the end of the lighter-bar D. Since the bearing that supports the spindle C is at the middle of the lighter-bar, the spindle receives just one-half of this adjustment. One turn of the hand wheel M raises or lowers the beater roll approximately one one-hundreth of an inch. Bevel gears may be, but seldom are, used in place of the worm gear and worm. At Z is a spiral cam. In case of an emergency, a pull on handle X will raise the roll one-half inch or more.

SPECIAL TYPES OF BEATERS

14. Defects of the Hollander.—There are a number of grounds for criticising the modern Hollander beater, among which are: larger power consumption; low beating capacity; insufficient mixing of the various ingredients of the furnish; large floor space required; and lack of close control over the beating operation. During the past fifty years there have been numerous attempts to improve on the design of the Hollander. These attempts have resulted in a large variety of engines of various kinds, which are being used to a greater or less degree. Some of the more important types will now be described in detail.

15. The Horne Beater.—One of the functions of a beater is that of *mixing*, and the ordinary Hollander beater was found to be faulty in this respect. By referring again to Fig. 1, it may be inferred from the plan view (a) that portions of the stuff

flowing next to the midfeather will remain there indefinitely, for there is nothing to throw them to the outside; and this will be found to be the case. The Horne beater (patented in August, 1886) was designed to overcome this deficiency, and is illustrated in Fig. 3. Instead of running with its top above the surface of the stock, as in the Hollander, the beater roll R is submerged, and instead of being placed at the center of the tub, it is located at one end. The midfeather M, as it approaches the roll, is
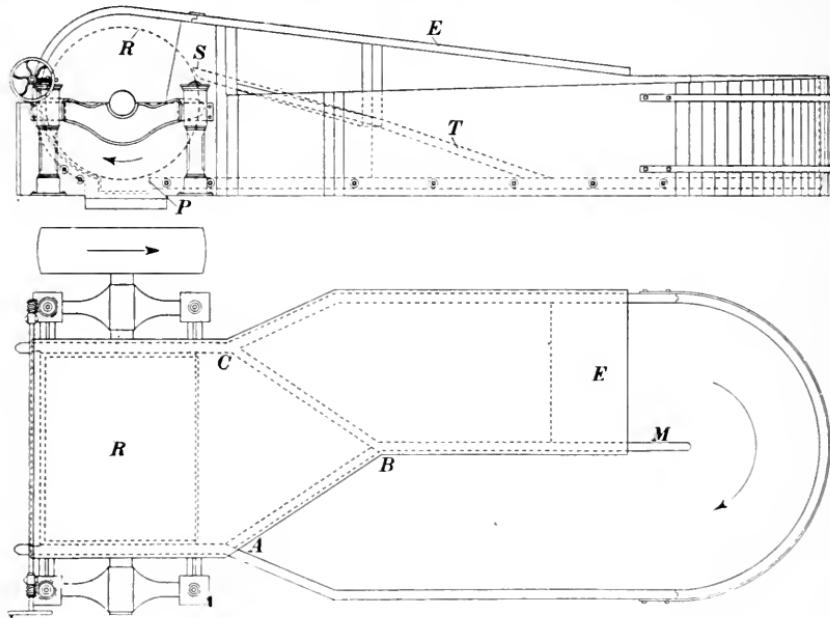
FIG. 3.

turned across the tub at BC, where the top joins the back-fall T, which ends in a shoe S that acts as a *doctor*, to deflect the stock from the roll. Thus the stock is carried between the roll R and the bed-plate P, thence around and over the roll, where it is deflected by the shoe S, and is sent back on the other side of the midfeather and under the back-fall at AB, to the roll again. The back-fall creates the head that forces the stock around the tub. As the stock nears the roll, the channel through which it is traveling becomes wider and shallower, finally reaching a width equal to that of the roll. Those portions of the stock, therefore, which approach the roll from a position next to the midfeather, actually return from the roll in a position next to the outside of

the tub. This action may be readily observed in a mill when the beaterman puts in the colors.

As the head of stuff over the shoe may, under some conditions, be considerable, the return side of the tub is covered with stout plank *E*, which extends nearly to the end of the midfeather, where the sectional area of the channel again becomes normal. The roll is carried and adjusted by the same type of mechanism that is used with the Hollander.

16. The Umpherston Beater.—Another deficiency of the Hollander beater is the large floor area required to operate

Plan

Section X-X
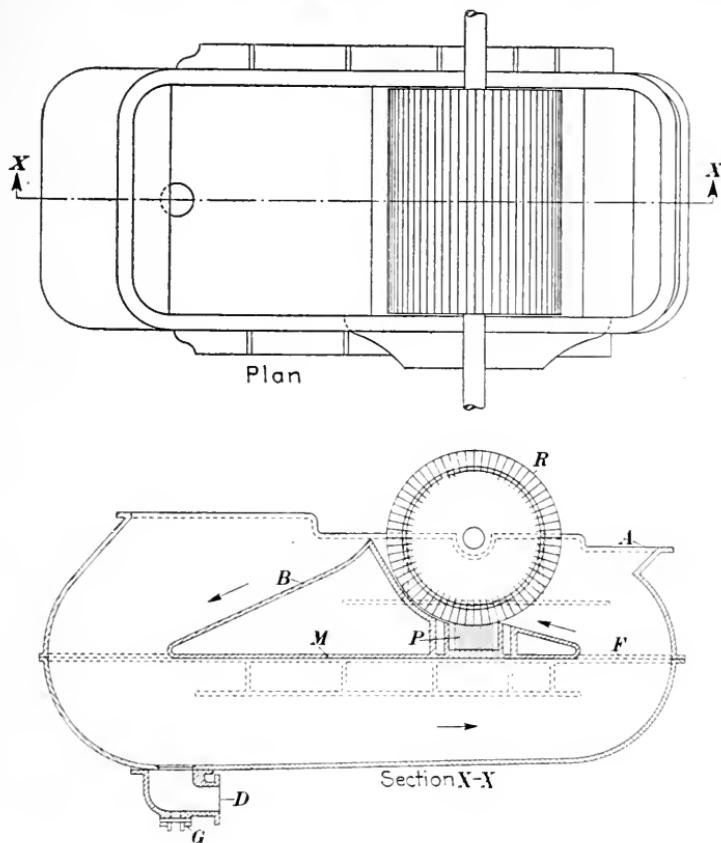
Fig. 4.

it. There have been many attempts to improve upon the Hollander in this respect, notably in the Taylor and the Umpherston beaters. The Taylor is rarely found in use now. but the Umpherston is on the market, and is not uncommon,

In both of these types, it is sought to economize floor space by circulating the stock, not in a horizontal path, but in a vertical one, passing downward through the floor and up again on the return.

The Umpherston beater is illustrated in Fig. 4. The tub, made of cast iron, is in the form of a shell, in two parts, set into the floor up to the level of the flanges F, where the two halves of the tub are fastened together. The midfeather M and the back-fall B are one piece, set in a horizontal position; and in the same casting is carried the chair for the bed-plate P. The stock is furnished at A and dumped through the spout at D. The cast-iron fitting through which the dumping is effected is provided with a packing gland G, through which runs a vertical spindle. The spindle operates a cap, or plug, fastened to its upper end, and raises the cap, to allow the stock to drop; it is also connected by a lever to a handle above the floor, which operates the valve. The roll R is shown conventionally.

17. The bed-plate is set in a cast-iron chair, or box, as in other types of beaters, and is driven to position between wedges; it is removed for repairs, or raised, through a cover plate on the side of the tub, just above the juncture of the two halves of the tub casting. The lighter mechanism, unlike the Hollander, does not have a lever, but consists of an L, or boot-shaped support T, Fig. 5, with the roll-bearing box B resting on the horizontal part (toe) of the boot. The vertical part may end in the form
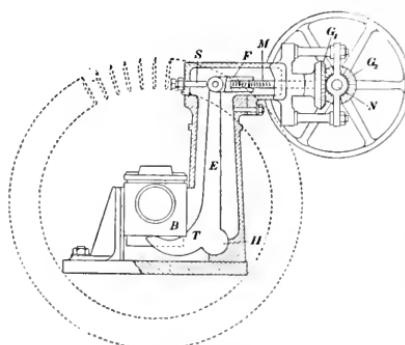
Fig. 5.

of a screw running in a composition-metal nut at the top. This nut is geared to a hand-wheel shaft, extending across the tub, by means of which, both ends of the roll spindle are adjusted exactly and together, similar to the hand-wheel mechanism of the Hollander. This mechanism is housed in a casting, also L-shaped, which rests on a bracket cast on the side of the tub; it is provided with a locknut adjustment, by means of which the roll may be alined horizontally. In Fig. 5, a variation of this arrangement is shown. Here the vertical leg E has a heel H

resting in a socket, and is connected at the top, by a pin joint, to a casting F. The latter is drilled and tapped (threaded) to take the screw M, which has bevel gear G_1 at the other end, and which is driven by G_2 on hand-wheel shaft N. Any movement of M will pull or push the top of E, which is the long arm of a bell-crank lever, and thus raise or lower the roll-bearing box B. A stop screw S fixes the lowest position of B; it can be adjusted to meet the conditions of stock and the wearing of bars.

18. The Miller Duplex Beater.—Inventors have endeavored many times to increase the amount of roll action possible during one circuit of the stock around the tub. Engineers have frequently tried to compute the effective work done by the roll on the stock, by multiplying the number of bars in the roll by the number of knives in the bed-plate, and multiplying this product
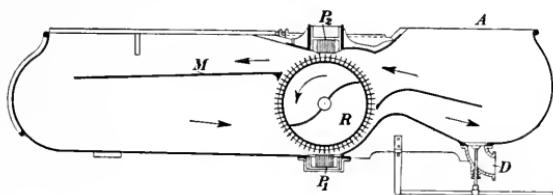
FIG. 6.

by the number of revolutions per minute of the roll, the final product being the total number of cuts per minute. However, a large part of the power used in driving the ordinary type of beater is required to propel the stock around the tub, and only a small proportion is required to overcome the friction of contact between the roll and the bed-plate; therefore, it is urged that more cutting action in the same capacity of tub will result in a more efficient beater.

A recent application of the foregoing reasoning is embodied in the Miller duplex beater, which is shown in Fig. 6. Its operation is similar in principle to that of the Umpherston, except that a second bed-plate is placed above the roll. The lower bed-plate P_1 is, of course, fixed in position, while the lighter mechanism, in addition to carrying the roll itself, also carries the upper plate P_2. The adjusting device that raises and lowers the roll is so designed as to move the upper plate P_2 exactly twice as far; thus the distance between the roll and the lower plate is always equal to the distance between the roll and the upper plate. Springs are

used to take up any shock on the upper plate in case of hard objects passing through. The dumping valve D is similar to that of the Umpherston.

19. The Marx Beater.—The Marx beater, shown in Fig. 7, is in line with the effort to obtain more roll action for the same capacity of tub. Here, however, there are two complete sets
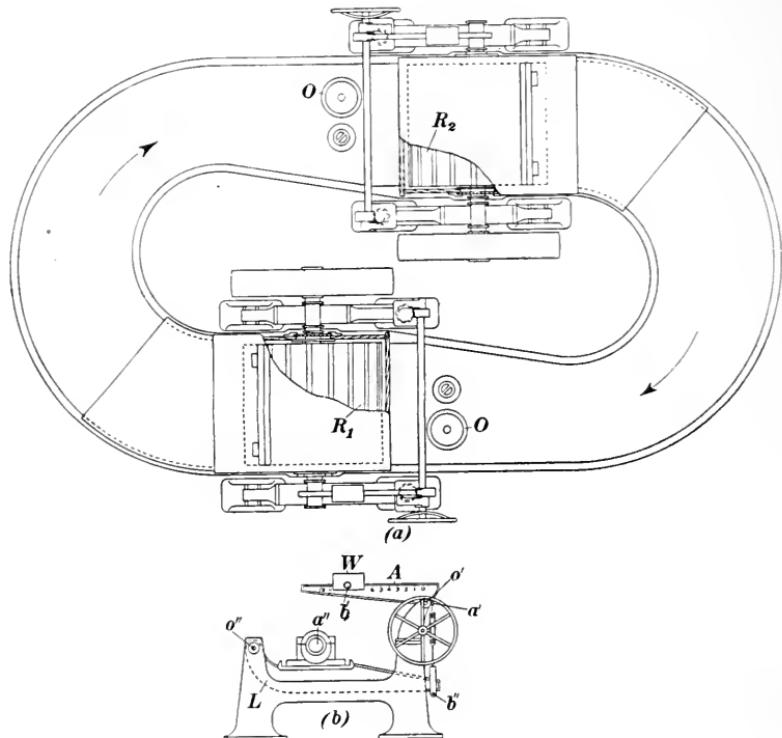
Fig. 7.

of roll and bed-plate, each with its own lighter equipment; and to accommodate them, the tub is designed in the form of a circuit channel, the midfeather being changed into an enclosure for the inboard lighter sets and pulleys. An advantage derived from this design is that one set of roll and bed-plate can be made of one type and the other set of another type, thus producing two separate kinds of action on the stock in a single circuit around the tub. In Fig. 7, roll R_1 is a stone roll, while roll R_2 has metal bars.

The lighter equipment, shown in detail at (b), Fig. 7, embodies a refinement in the adjustment of the roll, which is effected by a lever A and counterpoise W. By sliding the weight W outward on the lever, more of the weight of the roll can be counterbalanced, thus leaving less of its weight to act on the stock. It is to be noted that in duplicating the roll and bed-plate, it is also necessary to duplicate the dumping outlet O, because there are two low places in the bottom of the tub, one in front of each roll.
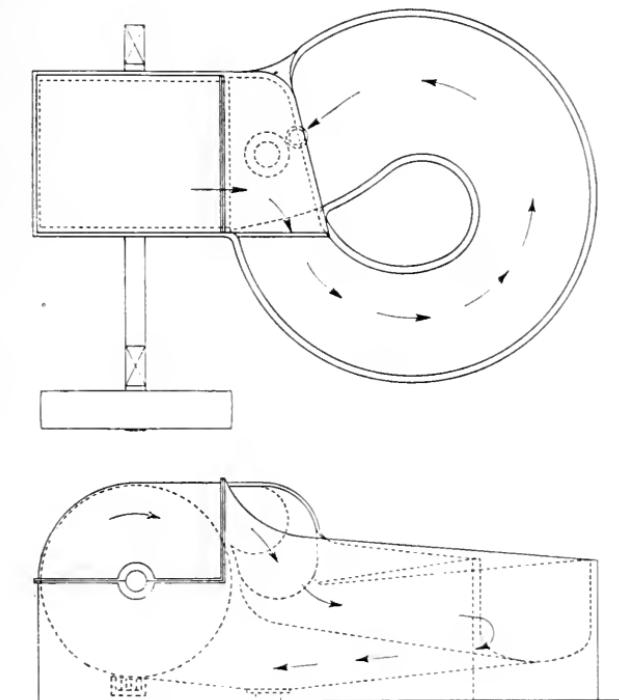
FIG. 8.

The roll, if made of stone, may be turned from a solid block and scored to form bars; or wedges may be set in special disks or headers. The selection of the stone is very important. Basalt lava is often best; it has small cavities, whose edges cut and do not crumble.

20. The Rabus Beater.—The Rabus beater, shown in Fig. 8, is similar in arrangement to the Horne beater. The tub, however, is modified into the form of a closed circuit, with open midfeather, in the effort to obtain more rapid circulation of the stock

with the same expenditure of power.   The channel is deeper, and
is shaped to facilitate the flow of stock and prevent lodging.
Note that the stock flows in a direction opposite to that in the
Horne beater, Fig. 3.

21. The Niagara Beater.—A very recent design, which has met
with great success on many grades of paper in reducing the power
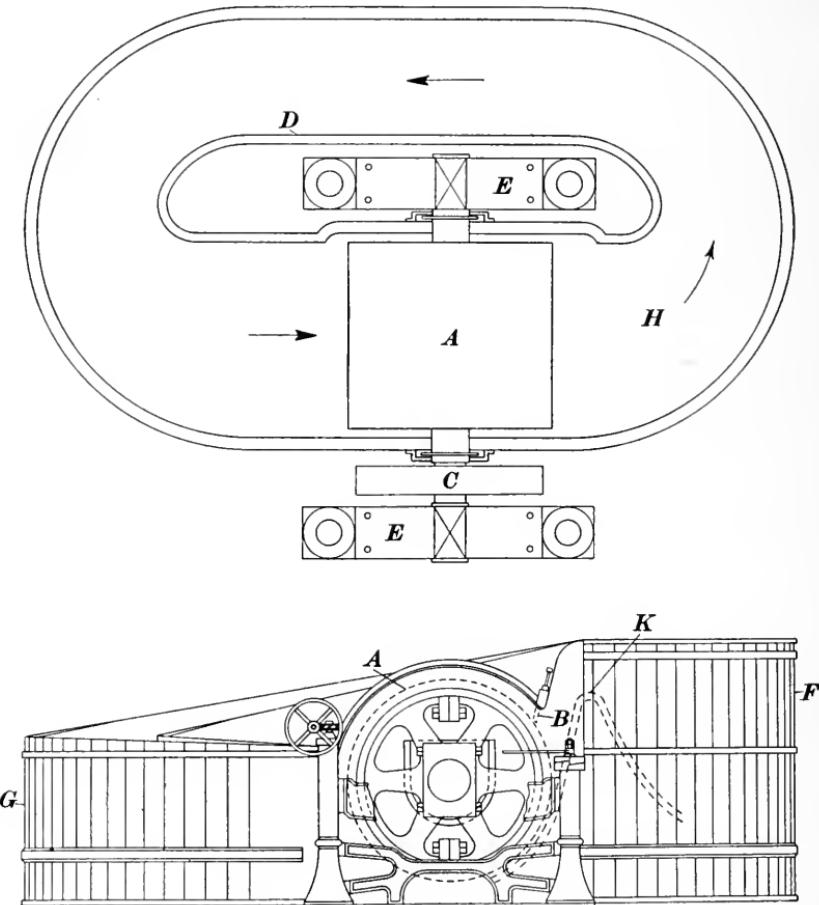
Fig. 9.

expenditure in beating, the time required, and the floor space,
as compared with the Hollander, is the Niagara beater, shown in
Fig. 9.   Great attention has here been paid to the design of the
channels through which the stock must circulate.   A U-shaped
bottom and a very high back-fall are employed; and there is a

marked difference between the width of the channel at the front side and at the roll side of the tub. Although the roll is not submerged, it has, nevertheless, the effect of being submerged, by reason of the great height to which it throws the stock over the back-fall, K. The marked reduction in time required for beating with this beater is attributed to the improved circulation of the stock, which not only allows the roll to treat the same portion of the stock more frequently but also renders a considerable portion of the power used in circulation available for mechanical work by the roll and bed-plate on the stock; and this is accomplished with an unusually high consistency of stock.

22. The Emerson Beater.—Another method of obviating the tendency of the stock that lies next to the midfeather to remain there is the device employed in the Emerson beater. The midfeather is made in two parts, exactly alike, set parallel to each other in one tub, with space enough between them to place the roll. The roll is mounted on a spindle that spans the entire tub, as in the case of the Hollander, with the lighter equipment standing outside of the tub. Thus, the stock passes under the roll in this central channel, over the back-fall; it is divided at the rear end of the two midfeathers, one half passing to the right and the other half to the left, in two separate channels, to the front of the engine, where the two streams reunite in the central channel and again approach the roll. In the Emerson beater, the tub is more nearly oblong in plan.

23. The Stobie Beater.—Probably the modern development of short-fibered chemical and mechanical wood pulps has brought forth no more bold departure from precedent, in the matter of design, than the Stobie beater. This apparatus could not be employed on long-fibered stocks, but it applies admirably to such materials as sulphite, kraft, soda and groundwood fibers.

An open-tub beater is used as a container in which to mix the ingredients of the furnish, and to break up the laps and dry broke[1] that may be used. The mass is then dropped into a chest, which is provided with a good agitator. Drawing from the bottom of this chest is a three-stage centrifugal pump, which is capable of

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[1] **Broke** is paper that has been discarded anywhere in the process of manufacture. *Wet broke* is paper taken off a wet press of a paper machine; *dry broke* is made when paper is spoiled in going over the dryers or through the calenders, trimmed off in the rewinding of rolls, or trimmed from sheets being prepared for shipping.

delivering the stock above the top of the chest to three or four fire nozzles, arranged in a battery and shooting horizontally, at a pressure of about 75 pounds per square inch. Before them is arranged a plate, the surface of which is serrated (something like the tread of an iron stair), and which is set at an angle that will deflect the stock downward again into the chest. In this manner, the stock is circulated from chest to pump, to nozzles, to plate and back to chest for a given period of time. It is then delivered to the paper-machine chest without any further refining. Stock at a consistency of 2.5% is circulated for a period of 20 minutes, the nozzles acting under a pressure of 75 pounds per square inch, the serrated plate being set at an angle of about 45 degrees. These conditions are roughly the average for a hard all-sulphite paper.

In power requirements, the pump is about equivalent to a large Jordan engine; and there is also to be added the power required to drive the breaking engine, in which, however, it is not always necessary to set down the roll. On rough computation, the Stobie beater would require about 120 horsepower-hours per ton of paper on a grade that would require about 370 horsepower-hours per ton of paper when beaten according to the usual methods; this represents a power saving of about 67%.

24. Besides the saving in power, Stobie's process affords the opportunity of gaining close control. Once the consistency has been governed, there are only four other variable factors: the pressure; the character of the plates; the angle at which the plates are set; and the length of time of beating. The character of the plate and the angle at which it is set may be fixed mechanically, and a recording pressure gauge will show both the pressure and the time. If, then, the management specifies what nozzle pressure to use and for what length of time the process must run on each furnish of stock, there is practically absolute control, with consequent uniformity of results, the only remaining condition that may vary being the characteristics of the raw stock. An accurately conducted beating process, however, tends to reveal such changes in the raw stock as may occur, and the management has the best opportunity to compensate for these, by making proper changes in the instructions governing the pressure and the length of time. In this way, it is possible for one good man on each tour to attend to all of the beating for a very large mill.

To just what extent this apparatus will apply to different classes of short-fibered stock and to different requirements as to finished paper, remains to be seen when mills in other lines of the industry are permitted to experiment with it. Certainly the elements of which the Stobie beater are composed, are capable of great modification, to suit different conditions; and this beater therefore represents, perhaps, the most hopeful, as well as the most radical development in beating equipment to date.

CARE OF BEATERS

25. Necessity for Exercising Care.—The very simplicity of the design and construction of most types of beaters tends to promote laxity in caring for them. This is particularly true in mills making coarse boards or saturating felts; and it applies also to mills using waste paper and cheap pulps, where the beater acts largely as a mixing vat and the roll is not lowered to any extent. But it is in mills making fine papers, where the beaters are carefully handled, that particular attention must be paid to the condition of the fly-bars and bed-plate, the adjustment of the deflector in the curb, cleanliness, power consumption, and the condition of the roll-adjusting mechanism and bearings.

26. Grinding of the Roll Bars.—During beating, the fly-bars of the roll and the knives of the bed-plate become worn, and they must be replaced from time to time. It has been shown that the bars may easily be removed from the roll; also that the bed-plate may be taken from the beater by removing a plate on the side of the tub, taking out the wedges holding the chair or box, and sliding the plate out. It is sometimes possible to continue to use a worn roll and plate by chipping out some of the wood between the bars, and thus have pockets deep enough between them to produce the necessary circulation.

27. After the roll has been filled, it is necessary to grind it to a true fit with its bed-plate; and the grinding must be done in such a manner as to insure that all bars come into contact throughout their entire length. The old way of doing this, which is still to be preferred where the finest beating is to be done, is to place in the tub, in front of and behind the roll, suitable dams. The

space between the roll and the dam is filled with fine, sharp sand, and the roll is turned against the bed-plate in this fine sand until the sound it makes and an inspection of the bars indicate a perfect fit. During this operation, enough water must be added periodically to prevent the development of too much heat.

A quicker method, but not so satisfactory for fine beating, is to remove the roll, mount it in a lathe, and bring the bars to their proper form by means of a grinding wheel. The bed-plate is then placed under a grinding wheel, which swings over a radius equal to that of the roll with which it is to run. In practice, this method is available only to the larger mills, because in smaller mills it is costly to remove the roll from the beater for refilling. It is generally desirable to grind a new roll also, except where it is to be used for coarse boards or felts.

In addition to the wearing down of the bars during beating, there is a change in the degree of sharpness or dullness of the bars, which is a very important factor in many classes of paper. Blotting paper requires sharp bars, whereas glassine and high-grade bond and ledger papers require dull edges on the bars.

28. Cleanliness.—In mills making white or colored papers, it is of importance that the equipment should be periodically washed, to remove dirt and other material that would show up in the finished paper. When running colored papers, the coloring is commonly done in the beater; and to the beaterman falls the task of seeing to it that every beater is washed free from stock carrying any color, before furnishing stock for a different color. This precaution is not restricted solely to the beater, but applies also to all the equipment through which the stock passes—head boxes, spouts, chests, pumps and refining engines. Moreover, beating equipment ought never to be shut down for more than a day without thoroughly washing out every part of it. The stock that adheres to the beater becomes very hard on drying, does not readily recover its water, and comes off in lumps, which will reach the paper machine wire to some extent and cause trouble and lumps in the paper. The fine-paper mills have a complete wash-up of the entire beating equipment at frequent intervals, regardless of any shutdown or change of color. In some cases, the spouts are constructed entirely of copper, with many hand holes; the chests are surfaced with the best glazed tile lining and all inner surfaces are kept clean. Sand traps and

pockets of all kinds should frequently be cleaned, to remove heavy particles of dirt and metal.

29. Use of Paint.—When the parts of wooden tub Hollander beaters are delivered by the builders to the mill, the metal parts are coated with white lead, and the wood parts, including the filling strips between the roll bars, are heavily primed with oil and white lead, for the purpose of preventing rust of the metal parts and the shrinking or checking of the wood parts. The outside of tub and curb are commonly finished with shellac and spar varnish; the inside of the tub may be finished with oil. In fine mills, during the periodic shutdown for cleaning, say once a year, the inside surfaces of the beater, including both roll and bedplate, are both thoroughly scoured free of the thin film of slime that collects from the stock; and the end spiders, or heads, of the beater roll are thoroughly scraped, to remove slime and rust, and are coated with red lead or some other anti-corrosion paint. It is claimed that aluminum bronze, properly applied, gives excellent service. Where cleanliness is of prime importance, it is generally the custom not to allow the stock to come in contact with wood or with a corrosive metal at any time; and in these cases, the wooden tub is lined with a non-corrosive sheet metal (copper), brazed at the joints, and roll and bed-plate are equipped with bronze bars. The roll heads are cast in bronze, or if cast in iron, they are sheathed as is the wooden tub. To make clean paper, the beater room must be *kept clean*, and the beaters, chests, etc. thoroughly cleaned periodically.

30. Swelling of Wood.—The tightness of the wood tub, and the accuracy of form of the beater roll, depend upon the swelling of the wood due to moisture. It is the swelling of the wood strips between beater roll bars that holds the bars fast. This swelling must have taken place before the roll is finally ground; for, however accurate the roll may be when dry, it will be thrown out of round when the wood strips are swelled. Moreover, a roll once put into service and ground to fit its bed-plate, cannot be allowed to dry; because, on putting it back into service, although the wood strips will swell again, they will not restore the roll to its former shape. If allowed to dry, it would be found seriously out of round and would have to be reground. Accordingly, a beater when shut down must have water in it, and the roll must be turned over once or twice each day to keep it in shape.

BEATER-ROOM EQUIPMENT

CHESTS AND PUMPS

31. Other Equipment Necessary.—In the preparation and supply of stock or stuff to the paper machine, there are several different types of equipment necessary besides the beaters. Since the beater has to be alternately filled (furnished) and discharged (dumped), which is an *intermittent* process known as the **batch process,** and since the paper machine, on the other hand, draws stock *continuously,* there must be in practically every installation, several beaters feeding a single paper machine. The intermittent supply of stuff from the beater is converted into a continuous supply through storage tanks (chests) and pumps. Gravity is taken advantage of wherever possible; but in practically all mills, stuff pumps are used for forcing the stock from the chests to the refining engine or to the paper machine. In addition to the above, there are auxiliary apparatus of various kinds, which are used in connection with beaters, or are used for regulating the flow of stock.

32. Mixing Chest.—Mills making low grades of paper, as for example news, use their beaters for scarcely any other purpose than to break up the laps of stock or to pulp the dry broke. They usually depend on the refining engine to prepare the stock for felting on the paper-machine wire. In some cases, the stock comes from the pulp mill in slush form, and is *mixed* in a tank or chest before being pumped to the refining engine. One form of such a mixing chest is shown in Fig. 10. The peculiar feature of this chest is the cylindrical coffer A, placed inside and rigidly supported from the walls of the chest. The agitator B is driven at a high speed, and is designed to propel the stock downwards. The bottom of the chest is deeply dished. Thus the stock receives more or less violent agitation and a thorough mixing. The stock outlet is at O, and the washout is at W.

33. Stuff Chests.—Stuff chests, shown at E and J, Fig. 20, are built in many different ways. The early designs were the same as an ordinary water tank, cylindrical in form, and made up of two heads, and with straight planks and staves, held tight to the circumference of the heads by iron hoops. Although this kind of chest is still very often found, it is being replaced by more

carefully designed chests; partly because chests of larger capacity are now demanded in mills of large production, and partly because the different character of modern paper stock requires somewhat closer attention to the design of chests and to the materials of which they are constructed.
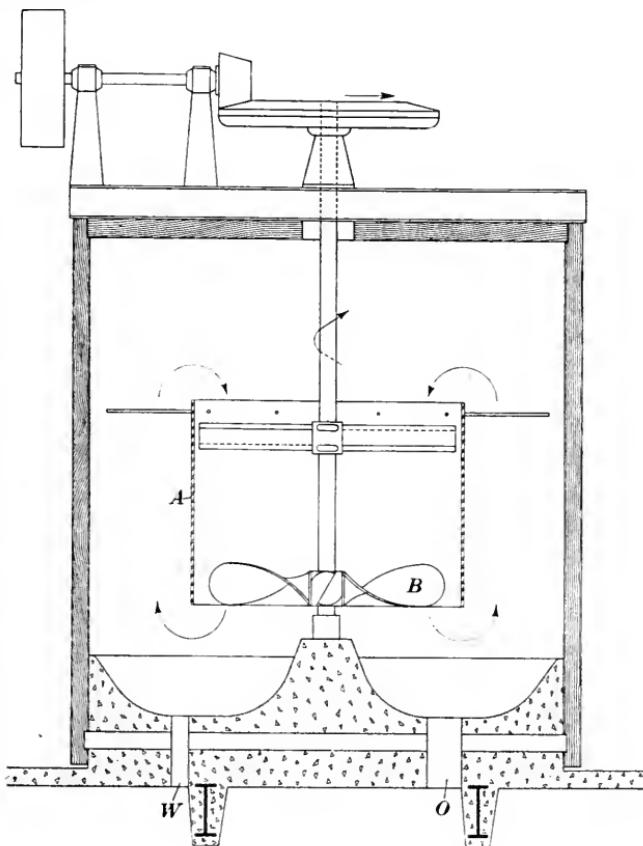
Fig. 10.

34. A very good type of stuff chest is shown in Fig. 11. This is a so-called *vertical chest*, built in cylindrical form, of concrete or brick, and lined inside with glazed tile. To set the tile lining properly requires the highest degree of skill on the part of the mason; because the surface has to be accurately smooth, and all the joints must be perfectly pointed with cement. In mills using a great deal of clay in the stock, this feature is especially important. The base of the chest has a fillet on the inside, to prevent the

lodging of dead stock at the juncture of side wall and bottom; and
the bottom itself is dished instead of being flat.   Both the service
outlet and the sewer outlet are placed near the center of the dished
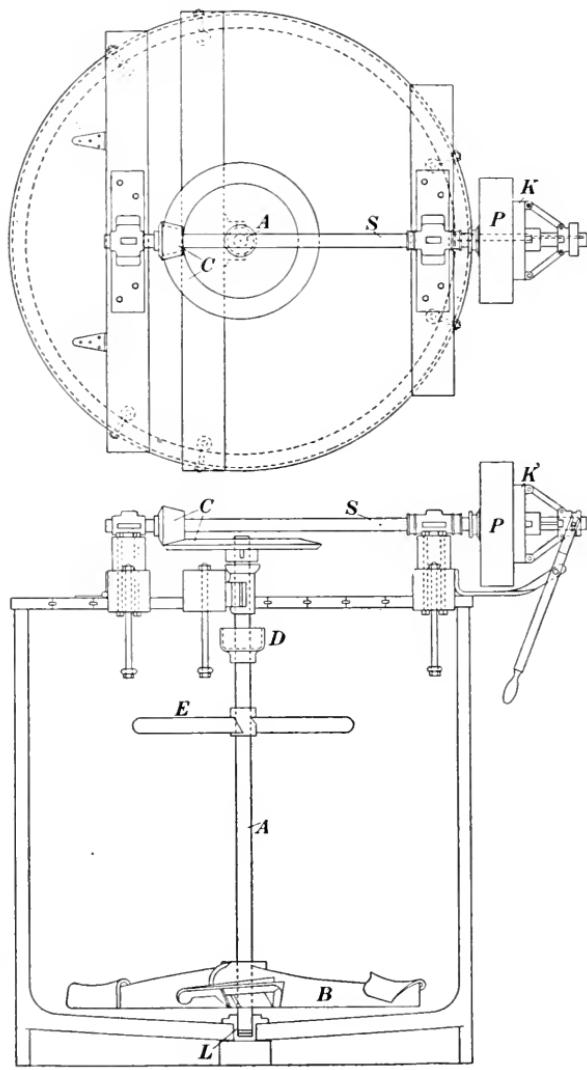
Fig. 11.

bottom, so all the stock can be run out when changing orders,
changing colors or shutting down. Similar chests are often
made of wood preferably, cypress.

A vertical shaft A, whose center line coincides with the center line of the chest, turns in a step bearing L, usually made of lignum vitæ and set in the bottom of the chest.   To this shaft is attached a series of agitator arms B, so designed as to throw the stock outward and upward along the wall of the chest.   At a higher point on the shaft A is another set of arms E, designed to throw the stock downward at the center.   Arms E are in use, of course, only when the chest is filled to their level or higher.   A cup D catches the excess oil that falls from the upper bearing of the vertical shaft.

Supported over the chest on a bridge tree is a shaft S and pulley P, with or without a clutch K, which drives the agitator through a cone pinion and crown gear C.   For a chest 12 feet in diameter and 10 to 12 feet deep, an agitator of this type should be driven at about 27 r.p.m., and will require from 6 to 8 h.p.   In mills making a good grade of paper, it is very important to have the chest well covered, as a guard against dirt.   Somewhere in the top, however, there is provided a peep hole, illuminated with an electric lamp, so the beaterman on the floor above can see at all times how full the chest is, and whether or not the agitator is running.

35. Horizontal Chest.—The vertical chest shown in Fig. 11, is preferred by some to the horizontal chest shown in Fig. 12, but
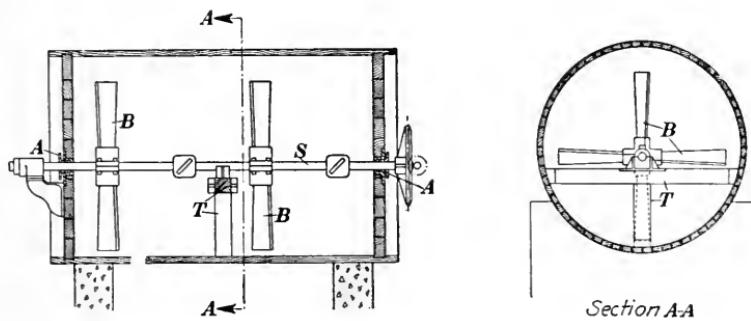
Fig. 12.

the latter type is by no means uncommon, and it may be required when there is but little head room.   As illustrated, it is a cylindrical wooden tank, built on its side.   The same type is also built of brick or concrete, without the upper part being arched over, the sides being carried straight up from the level of the center line of the agitator shaft.   The agitator shaft S is hori-

zontal; it carries arms B and is driven from the outside. T is a
support for the center bearing.   It is claimed that the horizontal
chest produces more uniform and quicker mixing.

36. Packing Gland.—Fig. 13, shows a typical packing gland,
in which the agitator shaft runs; it is adapted to either vertical
or horizontal stuff chests, and prevents leakage.   Such a gland
is used in vertical chests when the driving gear is below the chest;
otherwise, the bottom of the agitator shaft is usually set in a step
bearing in the bottom of the chest.
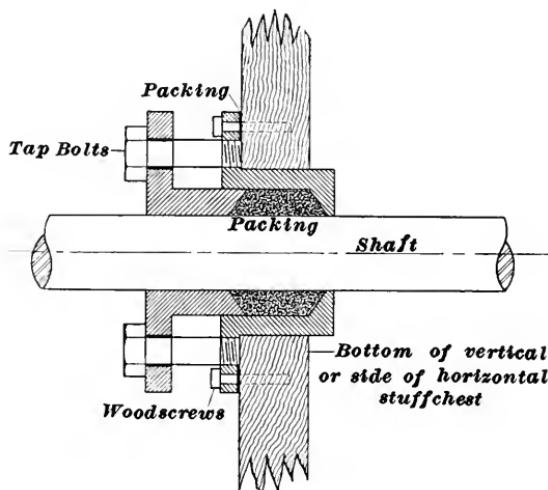
Fig. 13.

37.   Stuff Pumps.—The work done in lifting paper stock
from a lower to a higher elevation, as at points F and K in Fig. 20,
requires that the amount of stuff delivered per minute shall not
vary, whether the pump is drawing from a full chest or from one
that is nearly empty; under such conditions, the plunger pump
is used.   Each stroke of a plunger pump—sometimes called a
displacement pump—admits and discharges a fixed volume of
stuff.   Plunger pumps are designated as single (or simplex),
duplex, or triplex, according as they have one, two or three
cylinders.   Pumps of various types are described in an article
by E. F. Doty, *Paper Trade Journal*, beginning Jan. 4, 1922,
and *Pulp and Paper Magazine of Canada*, beginning Jan. 5, 1922
(see also Vol. V).

38. A duplex plunger pump is represented in Fig. 14.   It is
driven through pulley P, either with or without a set of reducing

gears, according as the duty of the pump is low or high. By means of a crank and connecting rod T, a long plunger K is moved up and down in the cylinder C, one on each side of the pulley. As the plunger rises, it leaves a partial vacuum behind it, which draws the stuff into the cylinder at the suction (or intake) end. When the plunger reverses its movement and begins to descend, it closes the suction valve and forces (discharges) the stuff in the cylinder through the delivery (discharge) outlet.

39. The manner in which the plunger pump works is shown in detail in Fig. 15, which represents a section through the cylinder of a simplex pump. The plunger A is long and hollow; and
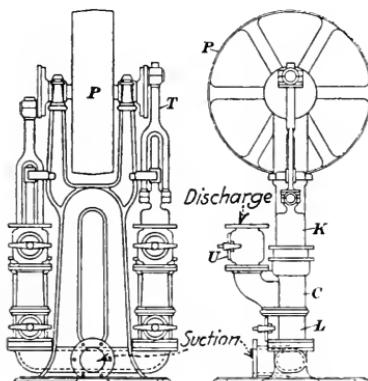
Fig. 14.
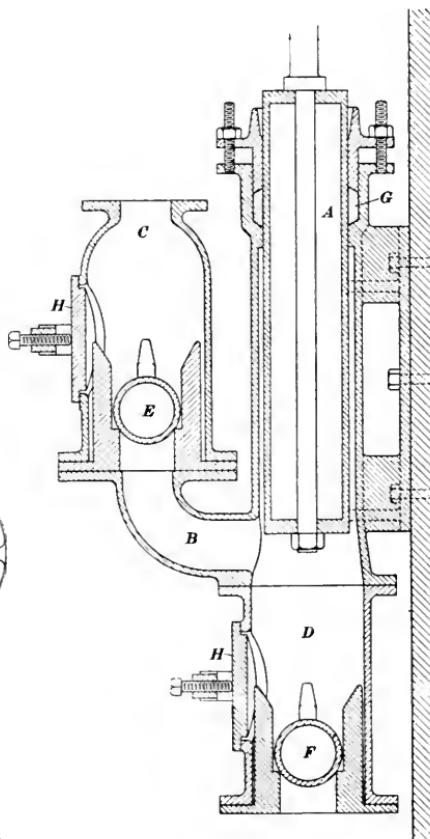
Fig. 15.

when in its lowest position, as shown, it occupies almost the entire volume of the cylinder D. The plunger runs through a packing gland G at the top of the cylinder. Directly below the cylinder is a hollow ball F, which acts as a valve, admitting stuff to the cylinder as long as the plunger moves upward. As the plunger starts to rise from its lowest position, it reduces the pressure behind it. The difference in pressure on the top and the bottom of the ball causes it to rise from its seat, and causes a flow of

stock upward, following the plunger. When the down stroke begins, the pressure on the top of the ball is greater than that beneath it; this forces the valve (ball) to its seat, which prevents the stuff from flowing back through the inlet pipe. As the plunger descends, the pressure increases; the stuff confined in the cylinder must go somewhere, or the plunger must stop, or the cylinder must burst; so the stuff flows through the discharge connection B, lifts the discharge valve (ball) E, and discharges through a pipe connected at C; this action continues until the plunger has reached the full limit of its down stroke. When the plunger again begins to rise, the pressure above valve (ball) E is greater than beneath it; this causes E to close (fall back to its seat), and keeps the stuff from flowing back from C; valve F rises, and the cycle is repeated. Both ball valves are made accessible by handholes, covered by plates H, which are held tight against gaskets.

40. Caution.—In operating a plunger pump, always keep in mind two very important precautions: first, never allow it to pump against a closed valve, for, otherwise, something must give way and serious damage must result; second, be sure that the stuff being pumped is free from foreign substances, such as small pieces of wood or rubber hose, which may get under the balls and cause the ball valves to leak.

QUESTIONS

(1) (*a*) What were the early methods of beating? (*b*) When was the beater invented?

(2) What processes are carried out that are incidental to beating?

(3) Suppose the roll spindle, Fig. 1, to rest at the center of the lighter bar D; if the rod K has a thread of $\frac{1}{4}$-in. lead, the worm gear L has 20 teeth, and the hand wheel M is given one-sixth of a turn, how far is the roll lifted from the bed-plate? Ans. $\frac{1}{900}$ in.

(4) Explain the circulation of stock in the beater.

(5) What are the objections to steel bars, and what other materials are used?

(6) In what respects do the Horne and Umpherston beaters differ from each other and from the Hollander?

(7) Describe a type of beater other than those mentioned in the last question, and give its advantages and its disadvantages.

(8) Would you prefer a vertical or a horizontal stuff chest, and why?

(9) (*a*) Why is the plunger type of pump well suited to pumping paper stock? (*b*) What precautions must be observed in operating it?

(10) What must be the minimum diameter of a cylindrical stuff chest under the following conditions? It is to hold two beaters of stock, each of which is to dump 1200 lb. of bone-dry stock, mixed with sufficient water to make its consistency 3 % (see Art. **69**); the total head room in the basement is 15 ft. 3 in.; 18 in. must be left under the bottom of the chest for piping, and the stock level must be kept at least 18 in. from the top of the chest; the bottom of the chest is 4 in. thick, and the weight of a cubic foot of stock may be taken as 62.5 lb.   Ans. 12 ft. 4 in.

AUXILIARY APPARATUS

41. Regulating Box.—The stuff pump must deliver a constant quantity, equal to the maximum amount of stock required for the machines. Provision must be made for times when less than maximum capacity is wanted. In Fig. 16, is shown in detail a very simple form of regulating box, which may be used as at G, Fig. 20. This is simply a wooden box A, divided nearly in halves by a partition B. The part ab is cut lower than the part bc, and the opening thus left is provided with a gate G, which can be adjusted by means of screw S, to close all or a part of the opening. The top of the gate G may be raised higher than the partition at bc. The partition D is higher than bc, but lower than the top of the box. When more stock is pumped into the box at E than is wanted in the Jordan (or the paper machine), the gate is raised until the excess stock passes over bc into compartment F, then down pipe H, and back to the chest. If the

Fig. 16.

stock is too thick, water may be added through pipe W. There are many designs of regulating boxes; some others are described in the Section on *Paper-making Machines*.

Some mills even have consistency regulators, so the stock pumped to the Jordan regulating, or flow, box is of very nearly constant density. A complete description of such an automatic regulating device may be found in Section 7, page 57, of Vol. III; it is briefly described in this Section in Art. **81**.
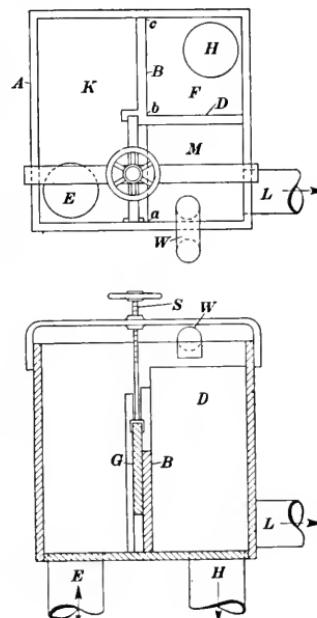
42. Washing Cylinder.—It is sometimes necessary to wash stock in the beater; or to increase its density (thicken it) by removing water. This is done commonly by means of a washing cylinder, such as that described in Section 1, *Preparation of Rag and Other Fibers.* This attachment is a set of scoops in a wire casing, which can be raised and lowered; it is caused to rotate, so as to dip up water without removing fiber.

43. String Catcher.—Fig. 17 represents an appliance for the open-tub beater, the object of which is to rid the stock of long strings, such as may be found in various classes of rag and rope
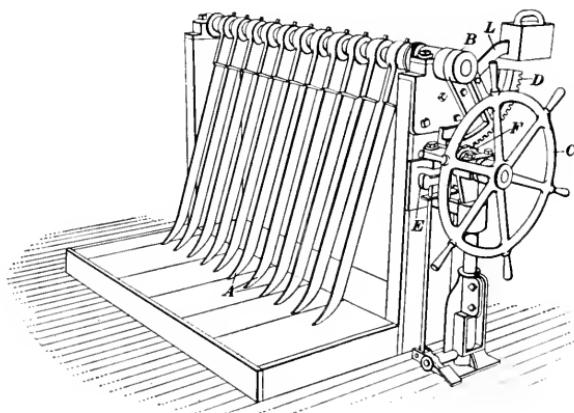
<p align="center">FIG. 17.</p>

stocks. The string catcher is mounted in the tub, in front of the roll, and acts in the same manner as the racks at the inlet of a water wheel. The arms A are mounted on a shaft B that spans the tub, and they are raised by means of a hand wheel C, geared to a quadrant D. The arms are held in position, when down, by a pawl E, which engages with a ratchet F, which is on the same shaft as the wheel. The lever L, attached to the shaft B, carries a weight that acts as a counterbalance to the arms A.

44. Continuous Beater Attachments—Shartle Attachment.— This consists of a casting that was designed to replace the back-fall of the ordinary Hollander beater. The surface toward the roll is perforated, and means are provided for the discharge of stock from under this back-fall. Assuming that the object of beating is to reduce the stock in fineness, or length, the perforations are so arranged that when the desired fineness has been

reached, stock will begin to pass the holes and on to the spout; as fast as this occurs, fresh stock can be added to the beater, which is thus converted from a batch to a continuous machine.

45. Bird Attachment.—Similar in principle to the Shartle, is the Bird continuous beater attachment, a perforated revolving drum being substituted for the perforated face of the back-fall. The drum is mounted in the channel of the tub that is opposite to that of the beater roll; it has perforations distributed uniformly over its face and over the end that faces the midfeather. The other end of the drum is open; and the stock that flows into the drum through the perforations is discharged through this end into a spout, which extends through the side of the tub, to a box outside the beater; the level of the discharge is governed by an overflow dam. The rate of discharge is governed by two factors: The size of the perforations relative to the fiber-reducing power of roll and plate; the difference in level between the stock circulating in the tub and the stock discharging from the spout. As rapidly as the stock is reduced by beating and discharged through the drum, fresh stock is added to the beater, thus making the process a continuous one. As with the Shartle attachment, it is assumed that the stock is beaten when the fibers have reached a certain fineness, approximately, and these attachments work most satisfactorily when this assumption is substantially correct; they are best suited to very coarse papers, such as roofing felts, leather board, and the like, and to the re-working of broke.

46. The Griley-Unkle Attachment.—The Griley-Unkle continuous beating attachment is also based on the assumption that the object of beating is to reduce the paper stuff to a certain degree of fineness. In this design, the perforated plate that separates the stock is located in the hood, or curb, of the beater, above the side of the tub and on the front side of the beater roll. The perforations are kept clear by means of a series of plates, which are made to slide over the perforations (like the damper slides of a cook stove), and which are driven by the action of a small crank that is belted to the roll spindle. The turning of the roll throws the stock off by centrifugal force; and as it becomes fine enough to pass through the perforations in the plate, it is collected in a trough, which is built under the perforated plate and entirely enclosed; from thence, it is delivered to the spouting system below the floor, through its own down-spout. A stream

of water is provided in the collecting spout, to thin the stock, so it will flow in the spouting system. The field of application of this attachment is similar to that of the two previously mentioned.

A particular application of this device is in the reduction of old papers, to prepare them for incorporation in the sheet, when this can be done without the direct action of the roll on the bedplate. If the slapping of the roll bars is relied upon to break up the stock, and this can usually be done in substantially the same length of time as under the old method of setting the roll down to working position, there is an approximate saving of 20% in power.

47. The Roll Counterpoise.—An example of the roll counterpoise was shown in connection with the Marx beater, Fig. 7. A graduated arm A is so hung that it gives a great leverage to the weight supported near one end of the lighter-bar L. The arm A is a lever of the first class, the power arm being the horizontal distance from o' to b', and the weight arm is the horizontal distance from o' to a'. Lighter-bar L is a lever of the second class, the power arm being the horizontal distance from o'' to b'', and the weight arm is the horizontal distance from o'' to a''. The whole constitutes a compound lever having a velocity ratio of $\dfrac{o'b' \times o''b''}{o'a' \times o''a''}$, which varies with the position of the weight W on the arm A; and more or less of the weight of the roll can thus be counterbalanced. With the weight W kept in a particular position, the bearing force of the roll on the bed-plate is constant. The action of the roll on the stock can, of course, be varied by moving the weight.

48. The Wallace-Masson Beater-roll Regulator.—With a given design of beater and a given type of filling in the roll and bed-plate, an effort is made to control the operation of the beater by so governing the adjustments of the roll that the roll will exert a given pressure on the bed-plate; the counterpoise shown in Fig. 7, is one method of accomplishing this. Another method is the Wallace-Masson beater-roll regulator, shown in Fig. 18. A frame spans the entire tub, in a line parallel to the axis of the roll spindle; it carries two pivot bearings T, in which are hung two levers F, both of which are connected to the piston rod in the hydraulic cylinder C. Levers F bear, at their outer ends, on

top of the lighter-bars H. The latter are counterpoised by means of levers L carrying weights W; and weights W are made sufficiently heavy to balance the entire weight of the roll, spindle, lighter-bars, and bearings, and the belt pull also, if it be downwards. The pressure of the roll on the bed-plate is thus independent of the weight of the roll; it is developed by admitting water, under pressure, to cylinder C, through admission pipe A, and relieving through exhaust pipe E. The exact pressure applied to the stock is thus registered by the pressure gauge D. By making D a recording gauge, a record may be had showing exactly what pressures were used at every minute of the day; and it will also serve as a basis for framing the instructions for beating. Since the roll is completely counterpoised, the bearing is provided with an upper half, or top bearing, through which the force necessary to produce the desired roll pressure must be transmitted.

49. The Adjustable Doctor.—In the better constructed beaters, the doctor that is placed at the back side of the roll, over the back-fall is adjustable. Those in charge of mills should watch the rolls carefully, to observe whether stuff is being thrown over from the back to the front; if so, the doctors should be adjusted to prevent this as much as is possible. While no great harm results from this carrying over, it tends to limit the capacity of the beater by reducing the speed of circulation of the stock. When adjusting the doctor, it should not be set so close to the roll that ordinary bumps bring the doctor and roll into contact.

In Fig. 19, is shown **Shlick's beater-hood attachment,** by which the Hollander beater may be so modified as to become a new type. The adjustable doctor D is connected with the lighter-
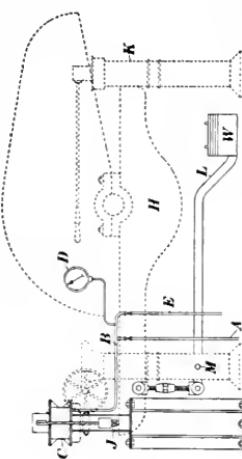
Fig. 18.
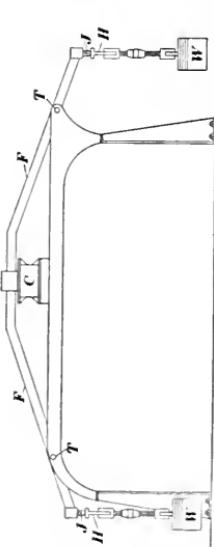
bar and in some cases to the roll journal, so that the doctor is raised when the roll jumps or is brought up by the wheel.

A high, deflecting hood or curb is indicated at *H* with correspondingly high back-fall, which, together with an elongation of the midfeather and heightening of the tub, increases the circulation of the stock.   The increased height of the back-fall is shown at *A* and *B*.   Many such variations are being developed and experimented with at the present time.
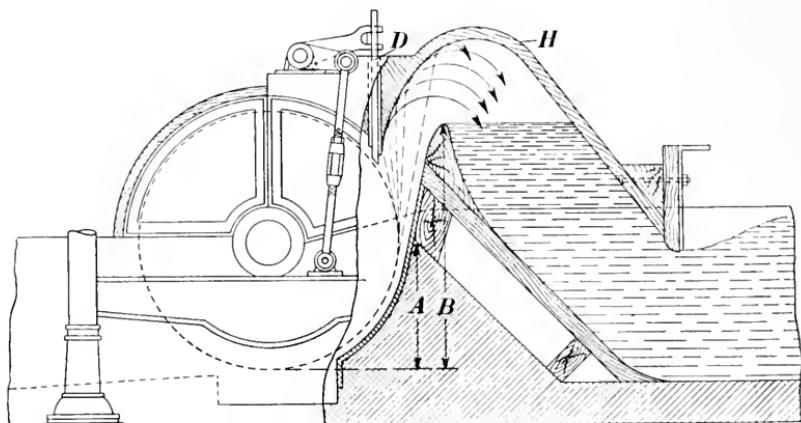
Fig. 19.

BEATER-ROOM LAYOUT

50. Fundamental Conditions.—It is probable that there are no two beater rooms in this country that have the same arrangement of beaters, chests, refining engines, mixing tanks, etc.   The kinds of pulps used, the form and manner in which the stock is brought to the beater room, the method of beating, the design of the building and the arrangements of the other parts of the mill, changes in arrangement or rebuilding of old mills, power conditions, size of the paper machines, and many other factors, affect the beater-room layout.   In general, however, there are certain fundamental conditions which are observed and which are considered when designing a new mill or rebuilding an old one.   The distance between the beaters and the chests should be as short as possible, and the down spouting should be (as nearly as possible) in straight lines with no sharp turns.   The pumps should be close to the chests, and the stuff-boxes and

flow-boxes should be close to the pumps, refining engines, and chests. Long drives or shafting are to be eliminated wherever possible. Two beaters, or even one, to one paper machine are often found in small mills or in mills where the capacity of the paper machine is not large. When the capacity of the machine is very large or where a considerable amount of beating has to be done on each furnish of stock, the number of beaters to one machine may be as large as eight. In general, it may be stated, that good design calls for a small number of beaters for machines of low capacity and a relatively large number for machines of high capacity.

51. Diagram of Layout.—For the purpose of illustrating the general relationships of the various pieces of equipment in the
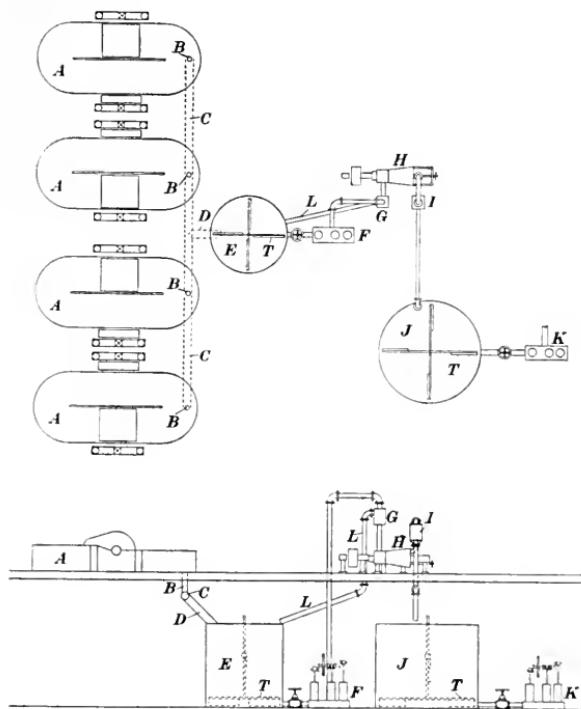
Fig. 20.

beater room, a layout of four beaters, two chests, flow-boxes, a refining engine, and pumps is shown in Fig. 20. The beaters A are arranged in a straight line, and the dumping valves discharge into vertical down spouts B, which lead to a collecting

spout C that runs under the beater floor, almost horizontally. The spout C should have a slight pitch in both directions toward the point of its junction with the single down spout D, which leads to the chest E. In the operation of the mill, assuming that fresh stock is furnished to all the beaters, they would be furnished in rotation, and would be dumped in rotation also. The stock thus passes in batches to the stuff chest E, which is built large enough to hold at least two beaters of stock, and which acts as a reservoir. Leading from the bottom of chest E is an outlet, through which the stock is drawn in a continuous stream to the pump F, which raises the stock to a flow-box G, placed above the Jordan refining engine. The flow-box is provided with a regulating device and an overflow pipe L; the latter returns to the chest E whatever the pump F throws that is in excess of what the paper machine requires to pass through the refining engine. The refining engine H, which will be described later, discharges in a continuous stream into a box I, by means of which the pressure imposed on the stock while passing through the refining engine can be governed; and from box I, the stock falls to the second stuff chest J. This last is the reservoir from which the paper machine draws its supply, through another pump K, just as chest E is the reservoir from which the refining engine H draws its supply; hence, E is known as the **Jordan chest,** and J as the **machine chest.** In many installations, box I is not included. Both of the chests E and J are provided with agitators T.

It is customary to place the beaters in pairs, as shown in the illustration, with pulleys adjacent. In this arrangement, the drivers are least in the way, and the free space left between beaters may be made sufficiently wide to afford trucking way when desired. This arrangement permits of a group drive, though the beaters may be driven in pairs or individually by motors. The group drive tends to put a more uniform load on the motor, when a motor is used as a source of power. Water wheels, when used as sources of power, are commonly connected to beaters in groups; this sometimes necessitates complicated belting and long lines of shafting, all of which consumes power and involves expense for maintenance.

FURNISHING THE BEATER

52. Composition of the Furnish.—The mixture of the various materials that are blended in the beater, and of which the paper is ultimately composed, is called the **furnish.** The chief constituent of this furnish is, of course, the fibrous material; and to this may be added rosin size, mineral substances, called **loading** or **filler,** coloring matter and alum (aluminum sulphate) in varying proportions, sodium silicate, starch, etc., as required. The kind of paper to be made determines the presence or absence of one or more of these non-fibrous constituents of the furnish, but nearly every paper requires the use of alum. The operation of filling up or charging the beater with these materials is called **furnishing.** The furnishing must be carried out in such a manner as to form a moving mass of slush throughout the process, which must provide for carrying the stock under the roll. It is a great advantage to have one kind of stock in slush or wet form, which can be drawn from a pipe or dug from a stock box, so that the circulation around the tub will begin at once. Lacking this, it is often necessary to make the initial slush by forcing some pulp under the roll with a paddle, after a small quantity of water has been put in; water alone will not carry dry or pressed pulp under the roll.

CONDITION AND HANDLING OF PULPS OR HALF-STUFF

53. Condition.—The pulp or half-stuff, the fibrous part of the furnish, may come to the beater room in many forms: dry or wet broke from the paper machine; pulped waste paper in cars from the drainer or in slush form from storage tanks; wood pulp in dry sheets, in rolls, or in dry or semi-wet laps; wet half-stuff in cars from the drainers; or various pulps in slush form or from thickeners. The handling of the stock in furnishing is as varied as is the beater-room layout and the form in which pulp reaches the beater room.

54. Pulping Broke.—In many mills, the beating equipment is utilized to pulp the dry waste of the mill. This is done in two different ways: (a) One or two beaters of the set are used exclusively as broke beaters, a small quantity of broke being dropped into the chest each time a beater of fresh stock is dumped; or (b) a proportion of dry paper is incorporated with each furnish, and

all beaters of the set are used alike.　By either plan certain beating capacity is withdrawn from the beating of fresh stock. In many mills some independent form of waste-paper pulper is preferred, which will deliver, for the furnish, stock that has been thoroughly wetted and reduced to a pulp.　One type of pulper for this purpose is shown in Fig. 21.

55.　This pulper consists of a hopper H, Fig. 21, mounted on a barrel B, the axis of which coincides with the axis of a shaft that is driven by a strong gear-reduction set.　The shaft carries radial arms C—see detail at (a)—which turn with their ends very close to the inside of the barrel B.　The dry paper enters the hopper with water and, usually, with steam also.　The mixture
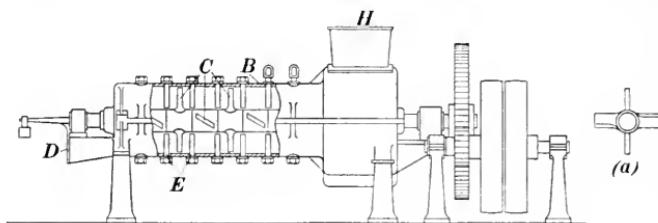
Fig. 21.

is driven toward the barrel by a worm-screw conveyor, under the pressure of which, it is forced through the barrel to the counterweighted discharge door D.　During its passage through the barrel, it is worked by the radial arms C.　These arms are cast with their forward face in the form of a cam, which tends to pinch the stock against the inside of the barrel and the pins E and to roll it at the same time.　The result is a moist pulp, which readily mixes with the other stock, when furnished to the beater. In many cases, it is possible to withhold this disintegrated paper from the beater until all of the fresh stock has been beaten, thus saving very greatly in beater capacity; it is then added with enough allowance of time before dumping to ensure thorough mixing.

Another type of waste-paper pulper, also used for mixing wood pulp, is described in the Section on *Treatment of Waste Papers*. It is essentially a beater, with a paddle wheel on one shaft for circulating stock, making about 14 r.p.m.　The other shaft is set with thin blades and makes 150 r.p.m., slushing the stock and mixing it.

56. Frozen Pulp.—Frozen laps of wood pulp are a source of considerable trouble in the beater room.   It is difficult to break up such laps by hand, and it is not always convenient to store
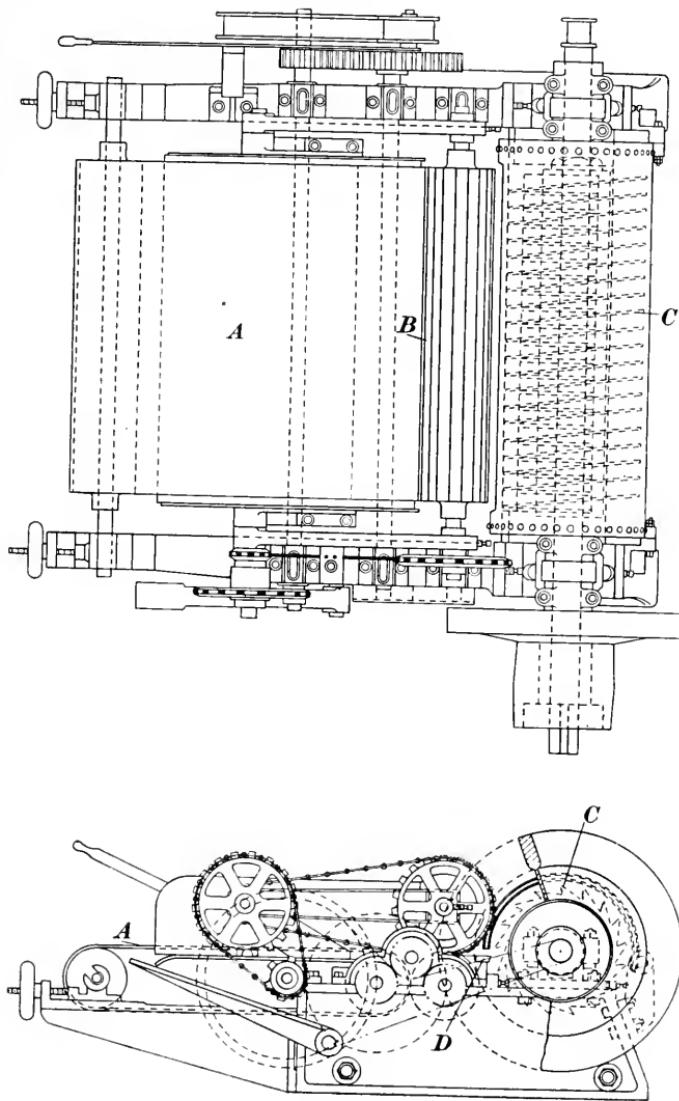
Fig. 22.

them indoors until they thaw; while to thaw them with steam is expensive.   If they are fed direct to the beater, damage may result.   To facilitate the furnish and to aid the beater in convert-

ing the laps into slush of the proper consistency, the use of a
machine is advisable. A patented shredder that is widely used
for this purpose is illustrated in Fig. 22. The stock is fed over
the feeding table A, and is passed on by corrugated roll B, while
it is torn into fragments by the blades C. These blades have a
serrated edge, and are so mounted on an arbor as just to clear
the steel shoulder D, which is mounted on the edge of the feeding
table. This machine is rated to consume less than 30 h.p. in the
preparation of 5 tons of dry stock per hour.

57. Slush Pulps.—It is common practice in news mills, and in
some mills making higher grades, to furnish the stock in slush
form. This is done where the preparation of pulp is under the
same management as the paper mill and the pulp mill is conven-
iently located, so that the pulp may be pumped directly to the
beater or fed by gravity from storage. Stock in slush form is
generally mechanical (*i.e.*, groundwood), sulphite or soda pulp,
or pulped waste papers. Where more than one slush pulp is
furnished to a single beater, separate pumps and piping are used.
It is customary to eliminate some of the water from these pulps
before furnishing them to the beater by means of various types
of thickeners, as explained in Section 7, Vol. III.

58. Dry and Semi-dry Pulps and Half-stuff.—Practically all
other pulps or stock are charged or furnished into the beater by
hand. Water is first put in the beater, and then the pulp or
half-stuff is added. Laps or sheets are broken up, and care is
taken that large lumps of stock are not permitted to go under the
roll. Half-stuff is dug out of drainer boxes in which it is pushed
to the beaters. Dry broke is added slowly, and with care not to
jump the roll. Pulp in rolls is generally added by pulling out the
center of the roll and pushing the end of the continuous sheet
under the beater roll. The roll of pulp is held pointing towards
the beater roll, which pulls the pulp in a continuous sheet from the
center of the roll. In other cases, the roll may be run on a piece
of pipe, held by two men, or in a frame.

ORDER OF FURNISH

59. Usual Order.—There are many and varying ideas regard-
ing the proper order for furnishing the different materials to the
beater. If stock is available in slush form, it should go in first.
If the stock is so thin that other stock added in the form of drained,

rag half-stuff, or dry pulp will not give the desired density, the excess of water is removed by the washer while the furnishing proceeds; then lap or roll pulp, or rags, or pulped paper is put in. Clay or other filler is usually added with the fiber or immediately after it. The order in which size, alum, and color are added varies with conditions; but, as a rule, the size is added early enough to allow for thorough mixing, and to have the effect of the size on the colors evident before the coloring has developed. Then the color is added and is well distributed, so that when the alum is finally put in, the coloring and sizing will be uniform throughout the mass. Exceptions to this order will be mentioned in the Sections treating of *Coloring and Sizing*.

60. Loading.—Mineral loading, or filler, is included in the furnish to give the paper opacity, to give the paper a smooth surface or finish, to assist in the development of the color (principally in white papers), and in some cases, to increase the weight of the paper. The usual loading materials are clay, calcium sulphate, and talc. Clay and talc can be added to the beaters dry. Clay and calcium sulphate (crown filler) reach the mill in casks, and have to be weighed into the proper batches for adding to the beater furnish. Clay is also bought in bulk in carload lots. Talc comes in sacks already weighed. If clay is used, the most satisfactory way to handle it is to mix it carefully with water in proper proportions, have a tank of it (which acts as a reservoir) mechanically agitated, and draw a prescribed volume of this clay milk into the beater while the stock is traveling. Further information concerning this operation is given in the Section on *Loading and Engine Sizing*.

61. Sizing.—The treatment of stock with a substance that tends to make the paper water- or ink-resisting is called **sizing.** The substance usually, almost universally, employed, where the sizing is done in the beater, is a soap obtained by boiling rosin with soda ash. This is added to the beater either by using dippers or by first emulsifying it in cold water and then adding to the beater in the form of milk. The latter method is finding increasing favor, largely because of its convenience, and also because of the better distribution throughout the beater that can be obtained by running in the milk while the stock is traveling. The chemistry of sizing is very complex, and it is not thoroughly understood. The important fact for the beaterman to keep in

mind is that two things are required in sizing: first, to add the size, and then to add the alum. Adding the alum (aluminum sulphate) to the furnish before the size has had time to become intimately mixed in all parts of the mass, defeats the sizing action. The subject is more fully discussed in the Section on *Loading and Engine Sizing*.

62. Coloring.—Adding the coloring matters is a part of the beaterman's duties. Here, again, the chemistry is very complex, and is still little understood, in some respects. Some coloring materials are better developed by following the alum than by preceding it in the furnish. More of the common paper-mill colors are better developed by being added before the alum, while with some it makes but little difference which is added first. However, the practical way of running a mill is to have a fixed rule, one that is nearest right on the average, and which will not involve a lot of men in the complexities of chemistry. With this in mind, chemists and color experts seem to agree that the best practice is to add the size early in the run, to add the colors at a time that will permit of thorough distribution and development, and to add the alum as near to the dumping time as is possible. The fact that the slight excess of alum that is always necessary will cause sufficient acidity to attack the steel of the roll and bed-plate is one more reason for this order of adding these materials.

The matter of matching shades and choosing coloring materials involves a world of intricate technology, which will not be discussed here. The subject of coloring is treated in the Section on *Coloring*.

TYPICAL FURNISHES

63. Reasons for Variation.—In order that the student may obtain a general idea of some of the principles involved in the furnishing and beating of stock for certain types of paper, a few illustrations are given. It must, however, be kept in mind that the method of furnishing, the order of furnishing, and the manipulation of the roll, will seldom be the same in any two mills, even on the same type or kind of stock. Experience has indicated certain general methods of procedure; but in a large number of mills, furnishing and beating are not under close technical control, and the skill and experience of the beaterman is relied upon to a

very great extent. Variation in the quality or character of the raw materials obtained is also a factor that makes it difficult to maintain the same formula for any given kind of paper. There are, therefore, so many factors which affect the furnish and the actual operation of beating, that the examples given must be considered to be very general.

64. High-grade Rag Bond.—Assuming the use of a 700-pound Hollander beater, half-stuff from number one "shirt cuts" (a high-grade of new, white, cotton shirt cuttings), an 8-hour beating for a high-grade, all-rag bond paper, and engine sizing sufficient for later tub sizing, the following procedure will give an indication of mill practice. Before adding any stock, or rather before dumping the previous beater, the roll is raised off the plate about 15 turns of the hand-wheel. This is necessary to give clearance for the bunches of stock. The beater is first filled about half full of water, which is carefully filtered, or strained through a cloth bag usually made of press felt. The half-stuff is brought up from the drainer room in "stock boxes," containing about 150 to 200 pounds air-dry fiber which, as it comes from the drainer, contains from 70% to 75% of water. The half-stuff is charged into the beater by hand, tongs, or forks, and in this case about $4\frac{1}{2}$ boxes of stock would be used. Water is gradually added as the half-stuff fills the beater. When completely charged with half-stuff and water, the concentration or density of the stock will be between 4% and 5%. The stock in the beater is very lumpy and the surface is not smooth.

After about a half hour of circulation of the stock, the roll is lowered 5 turns. At each succeeding half hour, the roll is lowered 2 turns until it is 2 turns off the plate, at the expiration of $2\frac{1}{2}$ hours. The rosin size is then added, (assuming that it is in milk form) from a measuring tank; 70 gallons of size, containing about 0.3 pounds per gallon are added, equal to 3% on the weight of the stock. It is preferable to strain this size while adding it. Strainers can be made by putting a bottom of machine wire or press felt on a shallow box about 2 feet square. By this time, the lumps of the stock have begun to disappear and the surface becomes more smooth. The roll is lowered by half turns each half hour until it is one-half turn off the plate. It is lowered a quarter turn at the end of the next half hour, and another quarter turn at the end of the next hour. The color, dissolved in hot or

cold water as the case may be, and strained, is added.   At the
end of 6½ hours, the hand wheel is turned down another quarter
turn, leaving the full weight of the roll on the stock.   About
25 pounds of alum, dissolved in hot water and strained, is then
added, and at the end of the 8-hour period, the roll is raised
15 turns, the valve opened and the stock is dumped to the Jordan
chest, with some additional water to slush it down.   This
manipulation is modified to a considerable extent by different
beatermen.

65. Mixed-stock Furnish.—Some furnishes may require the
use of two or more kinds of stock that require different beating
treatment, such as rag stock and bleached sulphite in a 50% rag
bond.   It often happens that the two stocks are beaten
separately, and mixed in proper proportions in the Jordan chest.
Care has to be exercised that there is proper mixing; and it is
generally necessary to have a special mixing chest, similar to that
shown in Fig. 10.   It is obvious that some such arrangement will
produce better paper, for the severe beating treatment to which
the rag half-stuff must be subjected may be detrimental to the
sulphite.   A similar manipulation is advantageous where rope
stock and sulphate pulp are used in strong bag papers, or where
rags and soda pulp are used in blotting papers.   In some cases,
it is common practice, where the proportion of long fiber (requir-
ing severe beating) is considerably greater than the short stock,
to charge the former into the beater by itself, and it is partially
beaten before the addition of the short fiber.   This method is
preferable to putting both stocks in at once, but it does not have
some of the advantages of the separate beating, as described
above.

66. Book Paper.—The furnishes for book papers will vary
widely.   Relatively cheap raw material must be used, and
production is an essential factor.   A rather high grade of book
paper would consist of equal amounts of sulphite and soda pulps;
these would be furnished to the beater by hand, and would receive
a short beating of about 2 hours.   For a 2000-pound beater,
about 10 bundles of 55% air-dry sulphite pulp or about 1000
pounds of dry sulphite would first be added, and the beater then
filled up with soda pulp.   Some 500 pounds of clay would
immediately be added, either dry or in suspension in water from
tanks.   This would give about 15% of loading in the finished

paper.   About 45 gallons of size would be added next from a tank, equal to 2% of the weight of the stock.   Color would be added shortly afterwards, the roll lowered, and the alum added shortly before dumping.   After 2 or 3 hours, the stuff is dropped to the Jordan chest.

Such a procedure or furnish is modified to a great extent where pulped magazine stock is used or where the pulps are available in the slush form.   In some cases, the sulphite pulp is beaten separately, and the pulped magazine stock or slush pulps are added in a suitable mixing tank or chest.   Most book papers contain clay, or some similar loading material, and also small amounts of rosin sizing.   It should be remembered that printing inks are made with oils, not water; hence, printing papers need not be water resistant.   In some cases, bleached mechanical pulp is used in the furnish, particularly where the paper is to be used for current magazines of little permanent value; such pulp is usually added in slush form.

67. Newsprint.—In general, newsprint is made of about 70% to 80% of mechanical pulp, the remainder being sulphite pulp, both unbleached.   Due to the necessity for low prices, costs must be kept to a minimum, and production is of paramount importance.   This type of paper is therefore generally made in a mill having a convenient supply of pulp; and it is probable that a majority of news mills use the pulps in the slush form, and have little, if any, use for a beater, except as a mixing vat.   Very small quantities of rosin sizing and alum are frequently added and, in case of "white" news, some blue dyes.   Any further conditioning of the fibers is done almost entirely by one or more refining engines.

68. Coarse Boards.—Probably the larger proportion of the tonnage of coarse boards produced have "mixed papers" as their chief constituent.   In the production of such boards as chip, binder's, cloth, trunk, etc., the waste paper is disintegrated in a beater or by special pulping equipment, and is fed direct to a refining engine.   Where combination boards are being made, the stocks for the different vats is beaten separately and dropped to separate chests.

THEORY OF BEATING

ACTION, POWER COST, AND EFFICIENCY

69. Definitions.—Certain terms are used by paper makers in connection with the treatment that the fibers receive in the beating process. Such words as *shortening, crushing, brooming* and similar terms are freely employed in the language of the mill as though they were accurately descriptive of certain phases of beater action. Unfortunately, however, in spite of the fact that experienced mill men are able to produce at will close and distinctive results in the beater, accurate knowledge regarding precisely what happens is limited; consequently, an exact wording of the meaning of the terms applying to these results is very difficult. General definitions of some of these terms will now be given.

Half-stuff is the fibrous material (pulp) in condition to go into the beater. When this material has been beaten, it is called **whole-stuff** or, simply **stuff.** When the whole-stuff has been diluted and is ready for the paper machine, it is called **stock.** Sometimes the words stock and stuff are used interchangeably, but a distinction should be made between them, to accord with these definitions. Note that in addition to the fibrous material, stuff may include other materials, as sizing, color, loading (filler), etc.

By **consistency** is meant the per cent of *air-dry* paper material in the stock (or stuff); also called **density** or **concentration.** It is found by dividing the weight of air-dry fiber in any particular amount of stock (stuff) by the total weight of the stock (stuff). Thus, representing the total weight of the stock (stuff) by W, the weight of the bone-dry material contained in it by w, and the consistency by C, $C = \dfrac{w \div 0.9}{W} \times 100 = \dfrac{1000w}{9W}$, because the weight of bone-dry pulp is 90%, or 0.9, of the weight of air-dry pulp or stock (stuff).

Free stock is a mixture in which the fiber has been prepared in such a way that when delivered on a sieve it forms a mat through which the water readily drains; this is an essential characteristic of stock for fast-running paper machines, as for newsprint and for papers that are to be bulky or absorbent. **Slow stock** has been

so prepared that, under the same conditions, the water drains
from it slowly; it is also called *greasy* or *slimy*, because of the feel
of the stock after very long beating.   Such stock requires a slow-
running machine and increased suction; it is suitable for bonds,
writings and parchments.   The terms **short stock** and **long stock**
are relative.   The fibers are shortened by being cut in the process
of beating or refining, or both.   A cotton fiber, perhaps $\frac{1}{2}$ inch
long originally, may be shortened considerably and still be longer
than a full-length wood fiber that is, say, $\frac{1}{8}$ inch long.   Short
fibers that are mixed with long ones tend to form a more closely
felted sheet than long fibers alone.   **Crushed fibers** are produced
by such action of beater or refiner as may be thought of as *pounding*.
Fibers, and bundles of fibers are sometimes split lengthwise into
what are called *fibrillæ*.   When this splitting affects only the
ends, the fibers are said to be **broomed.   Hydration** means the
taking on of water by the cellulose fiber; it is induced by the
mechanical action of the beating apparatus and the rubbing
together of the fibers.   Hydration results in a gelatinous film on
the fiber, which assists in cementing the fibers in the sheet.

ACTION OF THE BEATER

70. Mechanical Action.—Before discussing the theory of
beating, it would be well to consider the facts as to what results
are obtained by beating.   These results may be grouped into two
classes,—mechanical and chemical,—which, when combined to a
greater or less extent, produce the condition of the stock desired
for proper felting of the fibers on the paper machine.   The
change in the physical structure of the fibers may best be illus-
trated by photomicrographs.   It is to be noted that the cotton
fibers in Fig. 23, are quite long and unbroken; whereas, in Fig. 24,
the fibers are cut, bruised, frayed, broomed and split, and retain
little of their former unbroken character.   In this case, the stock
was subjected to prolonged beating, to "draw-out" the fibers
with a minimum of cutting action.   In the case of a rag blotting
paper, the tackle would be sharp, the consistency high, and the
cutting action greater than the bruising.   In Fig. 25 are shown
some unbeaten sulphite fibers,[1] while Fig. 26 indicates the damage
done to them by the mechanical action of the fly bars and bed

[1] Characteristic fibers produced by the several processes from wood
are shown in Section 1, Vol. III.

plate.   In the case of mechanical pulp, the beating results principally in a separation of fiber bundles.   Beadle[1] has shown, by the measurements of samples of stock taken from the beater at frequent intervals during the beating process, that the fibers are reduced in length, and that this reduction takes place largely

Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26.

during the early part of the beating.   It is, therefore, the general rule that, wherever there is any considerable beating, the physical structure of the fiber is changed by mechanical means.   The fibers to be used for paper making are thus shortened, frayed, split, etc., either in the beater or in the refining engine, to permit of better felting or interlacing of the fibers on the paper-machine

[1] Chapters on *Papermaking*, Vol. V, by Clayton Beadle, page 151, Fig. 29.

wire. The shake of the wire tends to form a compact and uniform fabric, which produces a better appearance and a more even surface for printing.

71. Chemical Action.—It is more difficult to describe or illustrate the chemical change produced in the fibers by beating. The simplest statement is that the cellulose fiber combines with water under certain conditions. This action is accelerated by agitation, by friction, or by treatment with certain chemicals. If carried to its extreme, this action results in a slimy, gelatinous mass, wherein all semblance of fiber structure has been lost; actual beating does not go this far, but some of this slimy substance is contained in nearly all high-grade papers. Glassine contains a high percentage of such hydrated cellulose, while blotting paper, in which it would detract from the absorptive capacity, has a very small percentage. Stuff that has been beaten a long time is generally slow or wet. The effect of this at the paper machine is to require more suction on the machine suction boxes, and to produce a more compact, dense sheet, hard to dry, and likely to cockle in drying. The hydrated cellulose acts somewhat as a binding material, and it tends to increase the tensile and bursting strengths of the paper by serving as a cement or binder; it produces a hard, rattly, snappy sheet. When a soft, limp, absorbent sheet is wanted, the beating is done drastically and quickly, cutting the fibers rapidly, and allowing as little time as possible for the development of the slime or hydrated cellulose.

72. How the Results Are Obtained.—Bearing in mind the various results obtained by beating, as they have just been described in general terms, it is necessary next to consider the ways by which such results are reached; and this may be done: first, with reference to the practical operation of beaters in paper mills; and, second, with reference to the theories of beating that have been evolved to explain the facts, as well as to assist in making improvements on present designs of beaters.

Take, for example, the case where all of the pulps that are to compose the final paper are beaten together at one time, for this is the simplest case. After the beater has been furnished and the roll action started, there is nothing added or taken away; no change can be made in the speed of the roll; no change can be made in the form, hardness, or number, of bars in roll or bedplate; the only manner in which the beaterman can influence the

quality of the final paper is by his manipulation of the roll up or
down, including not only his positioning of the roll, but also
the length of time of treatment at any given roll adjustment.
Upon this one factor, usually entrusted entirely to the skill of
the beaterman, rests the outcome; that is, whether the final
paper will or will not be of the required character, and whether
the paper machine can or cannot run economically.   The beater-
man judges the progress of the beating by feeling the stuff with
his hand, or by dipping out a small sample in a pan of about two
quarts capacity, shaking the stock together with additional water,
and observing the tendencies of the fibers to clot, or gather.

73. With the composition and the density of the furnish once
fixed, low setting of the roll, giving violent, drastic, punishment
to the stock, will result in the greater physical damage to the
fibers.   If this be maintained for a comparatively short period,
and the beater then dumped, the resulting stock will be free,
comparatively well formed in the paper, and the final paper will
be soft, inclined to be fuzzy, weak in tensile and bursting
strength, easy to tear, possessing low wearing endurance, and,
unless especially sized, absorbent.   Under the same conditions
in the beater, if the roll be set lightly, and that setting be main-
tained for a comparatively long period, the resulting stuff will
be slow, and, when run out into paper, will still be well formed,
but more cloudy, and the final paper will be hard, firm in surface,
strong, with high wearing endurance, and in much less need of
sizing to make it resist water.   A paper produced in the first
way will not take a high finish in calendering, whereas a paper
produced in the second way will readily take high-calender
finish.   Either action of the roll maintained for a long enough
period would result in slow stuff; but the two actions would
not result in the same quality of paper, except when carried out
almost indefinitely; in which case, the fiber would entirely
disappear and a gelatinous mass would remain.

By far the most usual procedure, for the higher grades of
paper, once the composition and density of the furnish have been
fixed, is to begin the beating with a moderate setting of the roll
and then gradually to lower the roll at intervals during the run.
Where the beating is done in this way, the beaterman must
decide how hard to set his roll at each change in setting, when to
change the setting, and when the desired final result has been
attained; great responsibility therefore rests upon the beater-

man. The task is the more delicate because of the fact, revealed by experience, that results are retarded and sometimes destroyed by raising the roll (setting it less severely) during the run. The roll must never be brought upward, but always progressively downward, except at the end of a run, especially if no Jordan is used, when the roll may be raised a hair's breadth, while the fiber is brushed out.

74. These rules in beating have been developed through years of operation with rag stock, and with other long-fibered stocks, for the higher grades of paper. Since the general introduction of wood fibers for the bulk of commercial papers of all kinds, refinement of practice in beating has tended to yield to rapidity, and the tonnage required of him leaves the beaterman little chance to attend to progressive roll settings. Most mills using wood pulps do their beating with a single setting of the roll.

The beaterman judges the setting of his roll by two means: first, by the number of turns of the adjusting hand wheel; and, second, more finely, by the sound that he gets by putting one end of a stick on the bed-plate chair and his ear to the other end. This same device tells him how well his roll fits the plate, and how accurately round the roll is ground.

75. Fibrage Theory.—Five years' experimenting by the Danish engineer, Dr. Sigurd Smith,[1] have led him to what he terms the *fibrage theory* of beating. As he points out, if a steel rod of square cross section is moved through a tub of stock, with its sharp edge forward, a certain amount of fiber will collect on that edge; and the character of the fiber and the density of the mixture in the tub determine how much fiber will thus collect. Similarly, as the beater roll turns, the bars advancing toward the bed-plate carry with them a certain amount of fiber collected on the edge. The roll bars then advancing across the bars of the bed-plate act on these fibers in a manner similar to the action of a lawn-mower on blades of grass; that is, it cuts some of them directly, but damages a great many more by fiber acting upon fiber within the mass that is imprisoned between the bars. Thus, if the consistency be thin, less fibrage will be collected on

[1] The Action of the Beater in Paper Making, by Dr. Sigurd Smith, Journal of the Royal Society of Arts, Vol. LXXI, No. 3655, Dec. 8, 1922. *Paper Trade Journal*, Vol. 75, No. 26; Vol 76, No. 1, Dec. 28, 1922 and Jan. 4, 1923. The *Paper Makers' Monthly Journal*, Vol. 60. No. 12, Dec. 15, 1922. Also in book form from *Pulp and Paper Magazine of Canada*, or Technical Association of the Pulp and Paper Industry.

the edges of the bars; and a given distance between roll and bed-plate will result in less fiber damage than if the consistency be thick and the distance between roll and plate be the same. This conclusion has been borne out by actual beating in the mill.

Acting on this theory, Dr. Smith has designed a type of beating tackle to impose on the stock greater action without a proportional increase in the power required. He explains that to make the bed-plate wider would not increase the effective beating that could be done under given conditions in a given time, a fact that has been shown in mill practice many times, as he says; and he offers as the reason, that in going across a single plate no new fibrage can be collected on the edge of the beater bar, and a comparatively narrow plate suffices to treat as much fibrage as is collected at one time. By arranging two plates, however, with a properly designed space between them, new fibrage can be collected on the beater bars as they pass from the first plate to the second; thus the second plate can be made effective also.

76. The Circulation Theory.—Granted that effective beating depends mainly on frequent passing between roll and bed-plate by the stock, there are then two ways in which this may be accomplished: First, to increase the number of plates under the roll, or, what in principle is the same, to increase the number of sets of rolls and bed-plates in one tub; second, with one roll and bed-plate, to increase the speed of circulation. By traveling more rapidly around the tub, the stock is brought more frequently under the roll; conversely, a beater that will propel a given concentration of stock at a higher rate of speed will propel stock of a higher concentration at the same speed. Stock of the higher concentration, as has been pointed out, will receive more damage to the fibers in one passage under the roll than stock of the lower concentration, the setting of the roll being the same. Thus, there is a double advantage in the beater that is so designed that, with slight increase of power, it can propel the stock at a higher speed; the effective beating may be increased either by reason of higher *speed of circulation*, or by reason of higher *concentration*. In practice, the newer designs that have been offered accomplish much in both directions.

77. Most Efficient Degree of Concentration.—An ingenious method has been evolved for finding the consistency of stock that will enable a given beater to perform most efficiently; that is, do

a given amount of work on the stock with the least expenditure of power per ton of paper produced. Based on the assumption that 50 times under the roll completes the beating, a series of tests were made on a given furnish at different consistencies, wherein the consistency, the speed of travel (circulation), and the power input to the motor, were measured; and these tests led to the following table:

Per cent consistency	Pounds air-dry stock	Speed of travel in feet per minute	Minutes required to turn 50 times	No. of dumps per 24 hours	No. of pounds air-dry stock per 24 hours	No. of tons per day	No. of horse-power-hours per ton
0	0	141	15.4	0.0	0	0.0	0.0
1	300	111	19.4	74.0	22,200	11.10	6.75
2	600	80	26.9	53.5	32,100	16.05	4.68
3	900	55	39.0	37.0	33,300	16.65	4.51
4	1200	33	65.0	22.2	26,600	13.30	5.64
5	1500	20	107.5	13.4	20,100	10.05	7.47
6	1800	10	210.0	6.85	12,330	6.16	12.18
7	2100	4	537.5	2.68	5,630	2.80	26.80
8	2400	1	2150.0	0.68	1,610	0.80	93.70

These figures plotted in the form of a chart are shown in Fig. 27. The chart brings to view more forcibly the fact that with this beater, and the particular stock with which it was furnished, the greatest production per day occurred when the consistency was 3%, and at that same consistency, the power consumed per ton of stock was least. If the consistency could be increased without reducing the speed of travel, and without increasing the power consumed proportionately, then
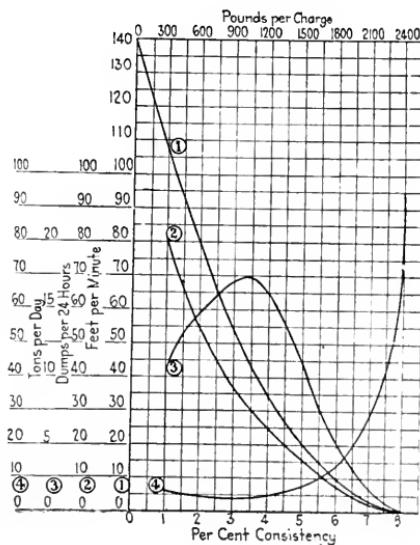
Fig. 27.

the efficiency of this beater would be increased; or if the speed of travel could be increased without reducing the consistency, and without increasing the power consumed proportionately, then the efficiency of this beater would be increased. To do either would require changes in the design of the beater.

78. The Viscosity Theory.—Experiments leading to the two foregoing theories have rested on the observed behavior of the stock in going over the paper machine, and on the quality of the final paper. The subject has been treated in this country from a radically different angle. Thus, the first step of the series of tests was to develop means by which small pulp sheets could be formed under exactly standard conditions; so that they could be tested in all of the known ways separately, and conclusions could be drawn, independently of the manner in which the beaten stock might be treated in the refiner or on the paper machine. Moreover, such sheets were made from samples of the stock taken from the beater at regular intervals during the beating; and, in this way, charts were constructed showing the changes made in bursting strength, folding strength, sizing, shrinkage, and bulk, *separately*, as related to the setting of the roll, the pressure exerted by the roll on the bed-plate, the speed of circulation, consistency, and power consumed. It was found, for example, that a given amount of beating, applied to a given stock at a given consistency, often increases bursting strength, but decreases folding strength, as compared with a less amount of beating; and the question arises, which manner of beating should be considered more effective. In other words, it is in many cases misleading to assert that a certain roll action, or a certain number of passages under the roll, constitute a given amount of beating; for such an assumption does not take into consideration all the facts. The amount of beating must be judged primarily by the particular qualities in the final paper that it is desired to have; then that manner of beating best adapted to enhance those qualities is the one to be selected.

The tests were carried out in the way described for seven years under a great variety of conditions, for the purpose of finding some method of so directing the beating of stock as to be able to repeat in a succeeding furnish of stock the same qualities, at the end of the beating, that had been produced in a previous furnish of stock. The key to the problem was finally found when it was discovered that changes in frictional resistance in the stock

have a direct bearing on the qualities of the final paper. With a given furnish and a given consistency, the action of the beater results in changes in the *surface* friction, and *internal* friction, of the stock. If these changes are made in the same way and to the same degree in one furnish after another, the final paper will possess the same qualities.

CONTROL OF BEATING

79. Two Ways of Controlling.—There are two ways of attacking the problem of control of beating: one way is to control the setting of the roll directly; the other way is to control the setting of the roll through measurement of the results of roll action on the stock. By the first method, the control of the roll directly, either the distance between the roll and the bed-plate, or else the weight exerted by the roll on the bed-plate, can be the factor chosen for control. But it must be clear at the outset, and always kept in mind, that if a beaterman is to be required to set the roll at the same distance above the bed-plate every time, or if he is to be required to set it upon the bed-plate with a given pressure each time, he must have some method of getting the beater furnished to the same depth and with stock of the same density; otherwise, these mechanical elements of control cannot be expected to give uniform results.

When no special instructions or apparatus are given to the beaterman, the condition of the stock and the manipulation of the roll are determined by him by the feel of the stock, or by the use of a small bowl or copper dipper, of about 2-quart capacity. Into this bowl, a small portion of stock is mixed with a relatively large quantity of water, and the appearance of the fibers and the absence of small clots or bunches of fibers are an assistance in judging the condition of the stock in the beater. Often two vessels are used, and the stock is observed as it passes over the edge of one to the other. Also refer to description of blue glass test in Section 3, Vol. III.

80. Control of Density.—A prime requirement of control of beating, then, is control of density (consistency) of the furnish, that is, of the percentage of paper-making material in the stock In one or two mills where this problem has received careful attention, methods have been worked out for weighing the pulp into the beater and measuring in the water. But pulp comes to

the mill in many forms and at different moisture contents; and to
be weighed correctly, it must be reduced to the same moisture
basis. A very effective device for doing this is a small centri-
fuge, such as is used by laundries for a preliminary drying of
clothing. It has been found by experiment that a sample of wet
stock, properly treated in a centrifuge, will always come out at a
uniform moisture content. In order to compute the weight at any
moisture content, it is only necessary to know what per cent of
moisture exists; therefore, the sample that is treated in the centri-
fuge gives the basis for all calculations regarding moisture; it
gives the beater-room management data for computing exactly
what quantities of the various stocks are to be weighed in, to
fill a given furnish, and what quantities of water to add. Until
this method was devised, the problem of furnishing definite
amounts of stock from the drainer, for example, has been almost
beyond precise control.

81. A Consistency Regulator.—A successful type of consistency
regulator widely used on wood pulps is shown in Fig. 28. Stuff
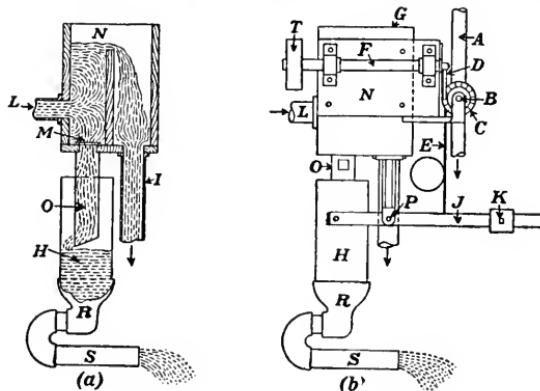
Fig. 28.

enters the constant-head box N, in the bottom of which is a round
orifice M in a brass plate. A constant head is maintained by
admitting more stuff through pipe L (pumped at a constant rate
from the pulp tank or Jordan chest) than can pass through the
orifice M, the excess overflowing the baffle into pipe I, which
conducts it back to the chest. That part of the stuff that flows
through orifice M passes through pipe O into the variable level or
weighing chamber H, which is mounted on a scale beam J that
balances on knife-edge bearings at P. The counterweight K

may be moved along the other arm of the beam as in any weighing machine, and is used to balance H and its contents.

82. Now it is well-known that the friction of stuff flowing in pipes varies with changes in consistency; also, if a relatively constant volume of stuff is to pass through a pipe of given size, it will require a greater head (or pressure) to maintain the same flow when the consistency of the stuff is increased.   This fact is made use of in the following manner:

Through a small bypass, taken off from the main stuff pipe, as close as convenient to the stuff pump, sufficient stuff is continuously drawn to maintain an overflow in the head box N of the regulator, thus maintaining a constant head on the orifice M, and producing a constant flow in the pipe O.   Since this orifice offers a minimum of frictional resistance to the passage of the stuff, the amount discharged through it to the variable-level chamber H beneath it, will vary but little with changes in consistency.   In passing from the variable-level chamber H, however, the stuff meets with considerable frictional resistance, which is governed by the reducing elbow R and by the size and length of the goose-neck outlet pipe S, with the result that the level in H rises a sufficient amount to overcome the resistance of the reducing elbow R and pipe S, and maintains the flow.   Thus, when the consistency of the stuff increases, the level in chamber H rises; and when the consistency decreases, the level in chamber H falls.

A water-supply pipe A is connected to the inlet of the stuff pump (which supplies stuff to be regulated) by means of a gate valve, the stem of which is connected to a screw B passing through a double-faced ratchet wheel C.   A pawl D is provided for rotating the ratchet wheel in either direction; a set of links E connects the scale beam J of the regulator and the pawl; a shaft F connects with an eccentric for operating the pawl; and a safety stop disengages the pawl when the valve is wide open or shut.

83. Stock of a given kind at a given consistency will fill weighing chamber H to a definite height; that is, where enough head is created above goose-neck pipe S to cause a rate of flow equal to the flow through orifice M.   Thus, a definite weight of stock plus metal is established for any desired consistency of stock; and this weight corresponds to such setting of counterweight K as will balance it.   The counterweight K is set to balance the weight of the chamber H and its contents at the desired consis-

tency, and when K and H are in balance, pawl D will not engage with either side of the ratchet. If the consistency of the stuff increases, the additional frictional resistance will cause the stuff to back up in chamber H, increasing the weight of the stuff in the chamber (since the level of the stuff in the chamber rises); this brings down that end of the scale beam to which chamber H is attached, and causes the other end, with the counterweight, to rise; this movement is transmitted by the links E, which cause the pawl D to engage with the ratchet wheel C, and rotates the ratchet wheel. Since the ratchet wheel cannot move sideways, it will cause the screw B (to which it is threaded) to back out and open the water-inlet valve until sufficient water is added at the pump to reduce the total volume of stuff passing through the pump to the proper consistency. When this occurs, the scale beam again becomes horizontal, the pawl comes to neutral position, engaging neither side of the ratchet, and the water valve remains open the necessary amount. If, now, the stuff becomes too thin and less water is required, an opposite movement (due to the same causes as just described) will close the valve the necessary amount. A safety stop disengages the pawl when the limits of the valve travel are reached.

If sufficient care be taken to insure proper operating conditions, stuff can be controlled with this apparatus with a maximum relative variation of 5% over or under the desired consistency. The same apparatus may be attached to the pump and pipe system delivering any kind of stuff from the Jordan chest, through the constant-head regulating box to the Jordan, or from the machine chest to the paper machine.

84. Instead of separate constant-flow regulating boxes delivering stuff of uniform density to the mixing tank, there may be used an automatic proportioning device recently developed. This consists essentially of the required number of constant-level stuff chambers, from which stuff is delivered through flat openings, which are provided with a slide valve that opens one part as it closes the other. With the proper proportions of pulp in constant quantity at uniform consistency thus insured, it is possible to add color, size, clay, etc., in solution or suspension in just the right amount.

85. Consistency Indicator.—The beater drag, Fig. 29, gives control of the consistency of the furnish; accomplished by bring-

ing the arrow L to a prescribed point and, at the same time, having the beater filled to exactly the same depth.   This result is effected most readily if one kind of stock is coming to the beaters in slush form; for, in that case, a steady stream of slush stock may be run in while water is taken out by means of a cylinder washer, thus maintaining the proper depth in the tub, until the arrow
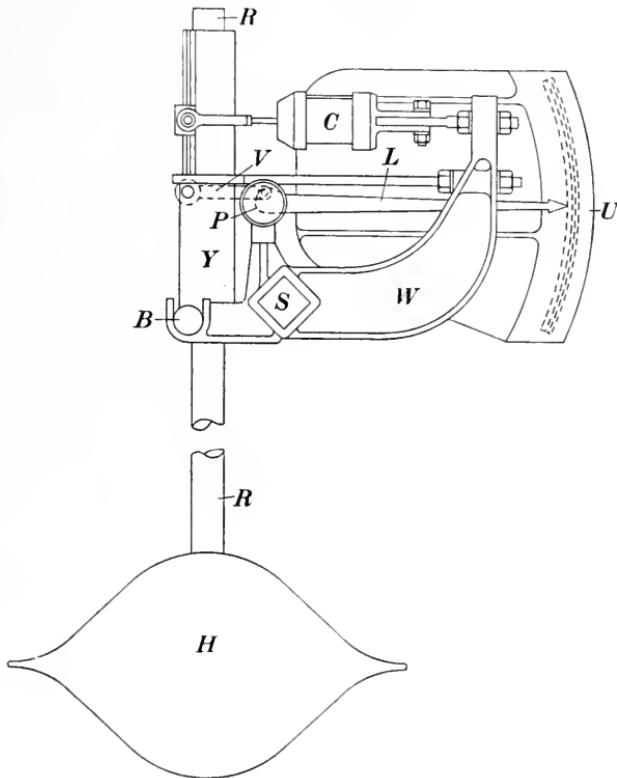
Fig. 29.

stands at the right point on the scale.   This method is sufficiently accurate in careful hands to control the consistency of the furnish within a relative variation of 2%.

86. Controlling Consistency at the Jordan.—In mills where no method has been adopted for the control of the density factor, it is customary to compensate for the fluctuation by adding water at the Jordan, adding more when the stock seems thick and less when it seems thin.   However, since density is the starting point in the control of beating, the better plan is to maintain uniform

consistency, when once obtained, from the beaters to the paper machine; this may be done by adding the proper amount of water in dumping, so that the consistency of the stock in the chest is kept uniform.   A very satisfactory device for this purpose is the **recording liquid-level gauge,** since paper pulps are of practically the same weight as water.   The diaphragm of the recording liquid-level gauge is placed well down in the chest; when it shows that the surface of the stuff in the chest has fallen to a certain level, the next beater is dumped, and the proper amount of water is used in dumping to bring the surface of the stuff up to a higher prescribed level.   If, then, this predetermined amount of dumping water is made such that the resulting consistency in the Jordan chest is right for passing through the Jordan, no water has to be added at the Jordan, and the uniformity of consistency once established in the beater is maintained up to the paper machine. It has been found that this factor can be so well controlled that ream weights on the machine almost maintain themselves.

87. Control by Setting of Roll.—Returning now to the plan of controlling by changing the setting of the beater roll, the same results in the stock will not be produced by the same position of the roll or the same roll pressure, as has already been shown, unless the consistency is the same.   But even with the consistency uniform, the quality of the stock coming to the beater varies. Some stocks require drastic roll action and some less drastic action, for uniform results in the paper.   That which requires less treatment will get over-treated, by being subjected to the same roll setting, as compared with that which requires more treatment, and the independent means of governing the roll setting would thus fail to compensate.   This method has been the subject of many careful experiments, in which both of the mechanical methods of governing the roll setting were employed. To obtain control of beating, therefore, it is necessary to develop some measuring unit to express the *result* of beater treatment on the stock.

88. Watt Meter Control.—It has been stated that a large part of the power used in beating is consumed in circulating the stock; with any one beater, this power consumption will be constant for the same furnish and consistency.   Any variation in the power consumed will then be caused by a change in the adjustment of the roll and its consequent pressure on the bed-

plate and effect on the stuff.   Any changes in power consumption are immediately reflected in the reading of a watt meter in circuit when only one beater is driven from a single electric motor.   By using a reliable recording watt meter, a curve is drawn that serves as a control and guide; and by duplicating the curve, it is possible to duplicate beating conditions very closely, although for really accurate work, this method is probably not so dependable as some others, because of the elements of beating action which it leaves out of account.

89. The Beater Drag.—The theory of beating control will be discussed later; but it may here be stated that the roll counter-poise and the Wallace-Masson beater-roll regulator both operate to govern mechanically the setting of the roll, whereas the beater drag, shown in Fig. 29, measures the changes produced in the stock by beating.

Referring to Fig. 29, a square shaft S spans the channel of the beater opposite that in which the roll runs; it is supported on guides at its ends, which are arranged to lift and fall on stanchions, through a distance sufficient to permit the drag to be lifted up out of the tub during the dumping and furnishing operations.   Fastened to the shaft S and held rigid by it is a frame W, which, in turn, carries a bearing B, by means of which an oval rod R, free to swing slightly, is hung vertically.   In Fig. 29, the stock is supposed to be traveling from left to right. Rod R is anchored back to frame W through a coiled spring, enclosed in spring case C.   There is a pivot bearing at P, which carries a light-weight bell-crank lever L, on the outer end of which is an arrowhead, which runs up and down across scale U. The inner end is connected by link V to the oval-rod bearing bracket Y.   At the lower end of rod R, is a smooth body or bulb H of proper shape, perhaps lemon-shaped.   As the stock thickens and creates a greater pull against this bulb, the rod R swings, which motion is conveyed through V to L; this causes L to rotate about P, and thus deflects the arrowhead upward; but when the stock is made thinner, the pull diminishes, and the arrowhead falls.   Each position of the arrowhead is recorded automatically by suitable clock-work mechanism.

As the beating progresses, a curve is automatically drawn on a chart, which represents the varying degree of pull exerted by the stock against the bulb H.   If the stock is furnished to a fixed depth in the tub at the beginning of the run, and the

arrowhead is brought to a predetermined point on the scale, the density of the furnish is thereby made uniform. The combination of a fixed furnishing point and a given curve on the record, composes the basis for instructions as to the beating; and the record of the recorder provides the history of every run, which may be compared with the instructions issued.

90. Experiments extending over five years, made both in the laboratory and under actual mill conditions, resulted in establish-
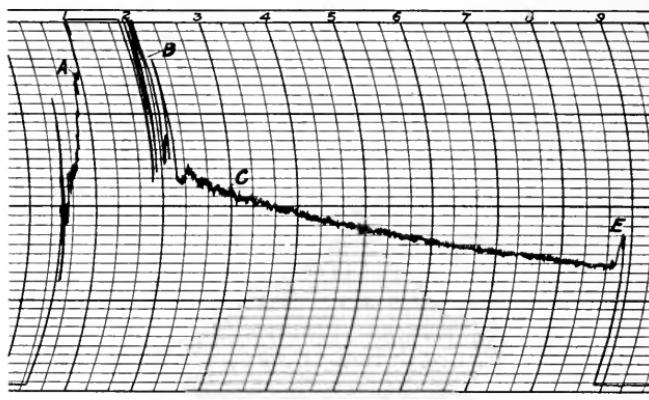
FIG. 30.

ing the following principle: The mass of stock in the beater is treated as a fluid mass, such as molasses; and the friction of this fluid mass on bodies that are made to move through it is measured, coupled with the friction of this mass when rubbing on itself. In other words, both the internal and surface frictions of the mass are measured. As the beating progresses, these frictional factors change. A typical curve, as drawn by the automatic recording attachment, is shown in Fig. 30. The principle is, then, that if this curve is reproduced each time that the same furnish is made in the same beater, the quality of the resulting paper will be uniform.

91. In Fig. 30, each horizontal line represents 10 points on the scale of the beater drag. The consistency of the furnish was determined by thickening with cylinder washer (Art. **42**) to point *A*. Thickening was continued until room was made in the tub for the size and clay, both in milk form, and they were added at point *B*, bringing the pointer down to *C*, where the first reading

was taken.   It is interesting to note at point E, where the alum
was added, that this had a marked effect on the reading, raising
it about 30 points.   To repeat this curve with the same furnish,
instructions are given in the form of a table of readings, one
reading for each period of time, say 15 or 20 minutes, throughout
the run; the beaterman adjusts his roll as the run proceeds, in
such a way as to follow out the readings as set, and thus duplicate
the curve.   Each different beater of the set on the same furnish
requires a different curve, because beaters do not have the same
action on the stock, even when in the same condition of repair or
wear.

Although this principle has not been applied in daily practice
to other than short-fibered stocks, a sufficient number of experi-
ments have been made to indicate that it has universal applica-
tion.   Long-fibered stocks require, however, a different form of
measuring device—one that will avoid snagging.   But the rela-
tionship between the frictional resistances and the quality of the
stock is apparently a universal principle, in connection with the
beating of stock for paper.

92. Control by Measurement of Freeness.—The freeness of
stock prepared for making paper decreases with the increased
degree of hydration of the fiber.   The progress of this action may
be followed and measured relatively by determining the rate at
which water will drain from the stock at standard temperature
and consistency.   The effect of temperature is not always fully
appreciated; it is, however, very important, since water at its
boiling point drains about five times as fast as water at the
freezing point.   It is also obvious that results can be compared
only when referred to stock of the same consistency.   Fig. 31
shows an apparatus used in a number of mills for measuring
the freeness of the stock; it is operated as follows: A cer-
tain quantity, say a quart, of stock from the beater is poured
into a sieve having a fine-wire screen bottom.   This is placed over a
coarsely perforated or grooved plate, a piece of felt is laid over
the stock, and is pressed down with a weight for a definite time.
A preliminary test will show about how much bone-dry fiber
is in the pressed cake.   On the assumption that this is nearly
constant for the class of fiber used, enough pressed fiber is taken
to make about 1000 c.c. of a suspension containing 1 per cent of
fiber.   Another portion of the cake is weighed and tested for
moisture content.   (A correction factor can be applied to the

test result, if necessary.) Thus, if the cake contained 50% moisture, 20 grams would be required to furnish the 10 grams to be mixed with 990 grams (approximately 990 c.c.) of water.

93. When thoroughly mixed, cool or warm to the temperature selected as the standard, and fill the container A, Fig. 31, to the mark, having first clamped the bottom and poured in water to the level of the wire screen B. The cover is then screwed on,
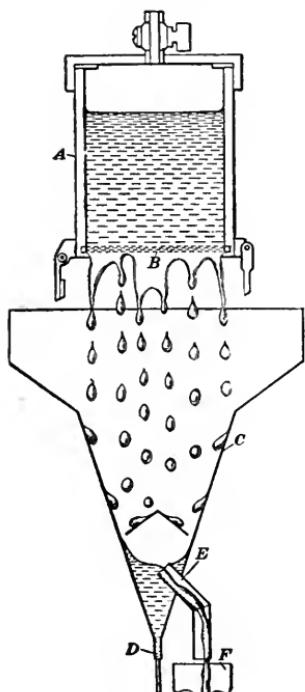
Fig. 31.

with the cock open; with cover closed, the cock is closed, and there is no air pressure in A. The container is placed over the funnel C, a vessel is placed under the bottom outlet D, and the side outlet E is supplied with a graduated cylinder F. The bottom of the container is opened quickly and kept from swaying back, and the cock in the cover is immediately opened. Water at once flows into the funnel, rapidly at first, then at a diminishing rate. While the rate of flow to C exceeds the capacity of outlet D the excess overflows through E to the graduated cylinder F. When the rate of flow to C falls below the capacity of outlet D, the overflow through E is automatically cut off. In the case of free stock, this cut-off from E is relatively late; in case of slow stock it is relatively early. Free stock will deliver more water to graduated cylinder F than will slow stock. The amount of water in F is a measure of the freeness of the stock.

Curves showing the variation in freeness can be drawn, and results can be fairly well duplicated with respect to those qualities controlled or indicated by this measurement.

94. A small centrifuge may be used for de-watering the sample, giving a uniform fiber content. Charts and curves may be prepared for correcting results of tests, both for temperature and for consistency. By using such correction factors instead of waiting to bring conditions of test to standard, fairly accurate indications may be obtained much more quickly.

QUESTIONS

(1) Explain the operation of the roll counterpoise. What advantage is taken of this principle in the Wallace-Masson attachment?

(2) Describe one type of continuous beater attachment.

(3) How does the beaterman know how close the roll is to the bed-plate?

(4) What differences in beating would produce a soft paper or a hard, rattly paper from the same furnish of stock?

(5) (a) Why is loading used in some papers? (b) Should loading be considered adulteration?

(6) What parts of the beaterman's duties could be served better if he had some knowledge of chemistry?

(7) In what way would you consider the microscope helpful in controlling the beating operation?

(8) How is freeness (or slowness) measured, and what does the result obtained indicate?

REFINING

REFINING ENGINES

THE JORDAN

95. Importance.—The refining engine, as shown at H in Fig. 20, is not a necessary part of the beating equipment; but, because of its usefulness as a means of preparing a stock that will form well on the paper machine, it is found in all mills of large production, and in most fine mills; while in mills making a low grade of paper, it has surpassed in importance the beater itself. The most common type of refining engine is the Jordan, named after its inventor.

96. Description.—A typical design of a Jordan engine is shown in Fig. 32. The working parts are conical in shape; they consist of a shell S, within which a plug R revolves, and to which it fits. Plug R is rigidly attached to a shaft, which turns in three bearings B, and is driven (in the case of a belt drive) by pulley P. Many Jordan engines are now installed to be direct-driven by electric motor, in which case, the motor is placed in line with the shaft of the Jordan, and is direct-connected to it by means of a special coupling, which permits horizontal movement of the plug, toward or from the motor. In some designs of direct drive, motor, plug shaft and plug, move together.

The Jordan is adjusted to govern its action on the stock by moving the plug horizontally, thus bringing its surface nearer to or farther from the inside surface of the shell. This action is similar in effect to the adjustment of the beater, when the roll is moved toward, or from the bed-plate. In the case of the beater, the surface of contact between the roll and bed-plate is very narrow—almost a line—while in the Jordan, the surface of contact is the entire inside surface of the shell. In the beater, the direction of movement of the roll during adjustment is at right angles to the axis of the roll; but in the Jordan, it is parallel to the axis of the plug. To effect this latter movement, the
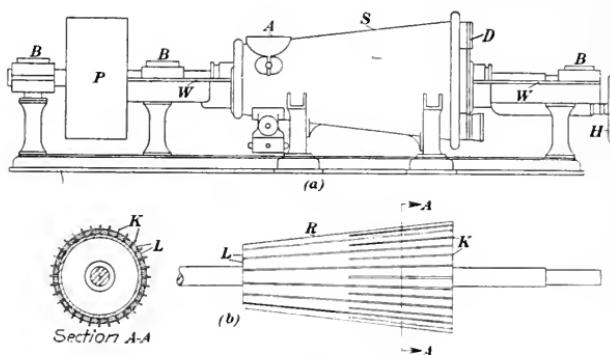
Fig. 32.

bearing shown at the large end of the cone is a thrust bearing, to enable it to withstand pressure action lengthwise along the shaft as well as to support the shaft from underneath. This thrust bearing is connected to a worm screw, which is fastened to the frame of the engine, and is operated by turning the hand wheel H. When the hand wheel is so turned that the plug, and the shaft to which it is keyed, move to the left, Fig. 32, the plug is set harder into the shell. The bearing boxes are fitted to run in machined ways W, in the same manner as the tool stand on a lathe.

97. The necessity for the thrust bearing is due to the fact that the plug is conical instead of being cylindrical. Since the surface of the plug makes an angle with the axis instead of being parallel to it (as in the case of a cylinder), any pressure acting on the surface may be resolved into two components, one of which will act parallel to the axis and the other perpendicular to it. The force exerted by the first component is the one that is resisted by

the thrust bearing. The larger the angle that an element of the cone makes with the axis the greater will be the horizontal thrust.

As has been stated, the beater is furnished and dumped alternately, a batch process; but the Jordan takes its supply from a chest, which is a supply reservoir, and runs continuously. The stuff from the flow box enters at A, Fig. 32, at the small end of the cone, and is discharged at D, at the large end. Both A and D are machine finished, to receive flanged pipe connections. The rotation of the plug at a relatively high speed, causes the stuff to swirl between it and the shell, and the result of this swirling is to cause the stuff to be thrown toward the large end of the shell by centrifugal force. The stuff passes through the Jordan in the form of a rather thin mixture, and it behaves very much like water. It is under considerably greater pressure at the large end of the cone, therefore, than at the small end, and the Jordan is consequently capable of throwing it up in the discharge pipe to a considerable height. The Jordan thus acts somewhat like a centrifugal pump. Both the Jordan and the beater employ the working parts to propel the stock, the latter by acting like a paddle wheel, and the former by acting like a centrifugal pump.

98. A view of the plug alone is shown at (b), Fig. 37. It is fitted with bars or knives K, which are set in slots, milled in the webs that support the roll (plug). These bars are firmly held in place by wooden strips L, wedged in between them when dry. The construction is like that of the beater roll, except that the Jordan plug is conical. The large end of the cone (plug) is fitted with more bars than the small end, because its higher peripheral speed produces correspondingly higher rate of wear.

The shell S is also fitted on the inside with bars similar to those of the plug. Evidently, some means must be adopted to prevent the bars of the plug from locking with those of the shell; this is usually accomplished by setting the shell filling so it slants, first one way and then the other, in herring bone style. Jordan engines, and other refiners, are sometimes arranged in series where more than one is provided for one paper machine. Less commonly they are placed in parallel.

99. Origin of the Jordan.—The Jordan refining engine is a development of an earlier machine patented by T. Kingsland, of Franklin, N. J., in 1856. The Kingsland engine was a flat disk,

with blades or teeth on both sides, set on a shaft, run in contact
with two stationary disks, one on each side, which were fitted with
similar corrugations.   It was in use in the mills of T. & R.
Kingsland, and was said to have produced some of the finest
book and "flat cap" on the New York market.   The intention
of the inventor was to devise a continuous process of beating that
would supplant the beater.

In 1858, the conical refining engine was patented by Joseph
Jordan, a paper-mill superintendent, and Thomas Eustice, a
resident of Hartford, Conn.   Many of the original experiments
leading to the perfection of the machine were carried out by
Jordan at Cumberland Mills, Me., in a book-paper mill, operated
by S. D. Warren & Company, and the work was much facilitated
by the encouragement of John E. Warren.   Jordan's work was
another attempt to supplant the beater; but, although this was
not accomplished, the work was so well done, nevertheless, that
the Jordan refining engine has come down to the present day with
no important modifications.

100. Caution.—If the refining engine is of the Jordan type,
that is, conical, it must never be left running without a supply of
water passing through it to cool it; for it will heat very rapidly
when running dry, no matter how far out the plug is pulled.   In
operation, it is kept cool by the stuff.

SPECIAL TYPES OF REFINING ENGINES

101. The Pope Refiner.—Although the Jordan is, by far, the
most common single type of refining engine, there are various
modifications of it in use, none of which, however, get very far
from the principle of the Jordan.

Proceeding on the general design of the Kingsland, which was
a flat disk that revolved on a horizontal shaft, the Pope refiner
develops a single face of contact between the disk and the
stationary plate, instead of the double contact employed in the
older Kingsland engine.   Further, the Pope is run at an exceed-
ingly high speed, and there is very little clearance between the
disk and the plate.   The setting of the disk against the plate
is as positive as in the case of the Jordan, the object being to
prevent any yielding when small bodies of material enter that are
coarser than the distance between the disk and plate, and to

maintain the fixed plate distance, thus reducing the size of such bodies to a practically uniform fineness. It was the intention of the inventor to bring foreign particles found in the stock to such fine dimensions that they could be incorporated in the final paper without detracting from its appearance.

102. The Claflin Refiner.—The Claflin refiner stands between the two extremes of Jordan and Pope refiners; it takes the form of a cone, with a wide angle, and it is, consequently, very short. The purpose of the Claflin is identical with that of the Pope, and its design is like a very short, stubby Jordan. Its plug and shell are filled in a manner similar to the Jordan. In practice, it is frequently set up in series, a number of separate machines taking the stuff, one after the other. This machine is illustrated in Section 8, Vol. III.

103. The Marshall Refiner.—The Marshall refiner embodies some of the features of both the Jordan and the Pope, or Kingsland; it is a machine of the same size and weight as the Jordan. At the large end of the cone, however, the shell is faced with an annular ring, the position of which is at right angles to the center line of the shaft; and the plug is provided with a similar annular ring, which takes the form of a shoulder or collar. Both of these rings are filled with bars or knives. The plug is set in hard against the shell, which brings this annular ring in contact also; and the stock, which is thrown from the small end of the cone to the large end, passes through this annular ring last, thus encountering more working surface than is provided in the Jordan.

104. The Wagg Jordan.—In the wearing down of the bars of the Jordan engine, it often happens that much of the knife edge of the bars becomes dulled. It can readily be seen that neither the plug nor the shell will wear out in straight lines. Owing to the different peripheral speeds at different cross sections of the cone, the knives tend to wear in spots; and the spots in which the wear has been slower will tend to hold the plug and shell apart at the points where the wear has been more rapid. This is the explanation of the "howl," which is heard, sometimes, for long distances from the mill. The result on the knives is that, where they are not in perfect contact, they erode under the scouring action of the stuff, and then become all the less effective. To obviate this, the Wagg filling was devised.

This consists of bars set in pairs, instead of being equally spaced, the two bars of a pair being not more than the thickness of the steel apart. If the forward bar erodes, the follower bar, being protected from the scouring, keeps more nearly to its original condition.

105. The Jordan Drive.—The preferable drive for the Jordan is a direct-connected induction motor, because of the ease of control through the electric-power meter, and also because this type of drive tends to maintain alinement. A belt drive, on the contrary, tends to wear the bearings in the direction of the belt pull, which causes the plug to work harder against one side of the shell than against the other side. In the case of stoppage of power in the beater room, the beater rolls must all be raised and the Jordan plugs pulled out, so that when the power is again applied, it will not operate at first against a full load.

106. Conclusion.—The beaterman's duties do not end when the stuff he has prepared passes from the Jordan engine to the machine chest; his responsibility continues until the stock is made into a satisfactory sheet. This necessitates close cooperation between the beaterman and the machine tender; each ought to understand the work of the other. The refining engine, serving largely as a fitter of beaten stock for the paper machine, comes near to the machine-tender's sphere; in some mills the refiner is in the machine-tender's charge. Whatever the line of division, however, cooperation and harmony are the keys to success.

QUESTIONS

(1) Make a pencil sketch of a Jordan engine and tell how it works.

(2) Describe one type of refining engine other than the Jordan.

(3) Should the beater room and the paper-machine room be considered as two distinct, separate, and independent departments?

BIBLIOGRAPHY

Beating.
> Eberhardt, Max: Wochbl. Papierfabr., Vol. 51, No. 47, pp. 3319–21; No. 48, pp. 3391–5, Nov. 27, Dec. 4, 1920.

Beating.
> Shartle, Charles W.: Year Book, Am. Pulp & Paper Mill Supt. Ass'n, 1920, pp. 119, 121.

Beating.
> Stewart, O. C.: Paper Trade J., Vol. 72, No. 24, p. 30, 1921; Paper, Vol. 28, No. 15, p. 14, June 15, 1921; C. A.,[1] Vol. 15, p. 4050.

Beating, Concerning the Theory and Practice of.
> Beadle, Clayton: Vol. V of Chapters on Papermaking: Crosby, Lockwood and Son, London, 1908, pp. 182. German translation appeared in 1911.

Beating, Consumption of Power in.
> Campbell, W. B.: P. P. Mag. Can., Vol. 18, No. 43, pp. 1087–8, Oct. 21, 1920.

Beating of Pulp, Notes on the.
> Varlot, J. G.: Bull. Ind. Fab. Papier et Carton, No. 3, pp. 40–4, Feb. 1, 1920; C. A., Vol. 14, p. 1039.

Beating of Paper Pulp, Notes on.
> Alison, Wm.: World's Paper Trade Rev., Vol. 77, No. 11, pp. 832, 4, 6, 8, 858, Mar. 17, 1922; Paper Makers' Mo. J., Vol. 60, No. 4, pp. 133–6, discussion, 137–9, Apr., 1922; Paper Maker, Vol. 63, No. 4, pp. 481–3, Apr., 1922; Paper Trade J., Vol. 74, No. 19, pp. 55–7, May 11, 1922; Paper, Vol. 30, No. 21, pp. 7–10, July 20, 1922; Proc. Tech. Sec., Great Britain, Vol. 3, No. 1, pp. 40–6, Oct., 1922.

Beating, The Degree of, Apparatus for Testing.
> Paper, Vol. 14, No. 5, pp. 19–20, Apr. 15, 1914.

Beating, Testing the Degree of, Apparatus for.
> Schopper, Alfred: Papier-Ztg., Vol. 39, pp. 642–5; C. A., Vol. 8, p. 1502.

Beating, Chemical Changes during.
> Schwalbe, Carl G.: Wochbl. Papierfabr., Vol. 51, No. 21, pp. 1486–9, May 29, 1920; Chem.-Ztg., Vol. 44, p. 458, 1920, Vol. 45, No. 53, p. 1883, 1920.

Beating, Developments in.
> Green, Arthur B.: Paper, Vol. 23, No. 23, pp. 22, 24, Feb. 12, 1919.

Beating and Beating Engines.
> Shartle, Charles W.: Paper Trade J., Vol. 75, No. 22, pp. 20, 22, 24, 26, Nov. 30, 1922; Paper Mill, Vol. 46, No. 47, pp. 12, 28, Dec. 2, 1922.

Beating of Paper Pulp, the Degree of, Apparatus for Determining.
> Skark, E. W. L.: Papierfabr., Vol. 11, p. 1358; C. A., Vol. 8, p. 1205.

Beating, the Degree of, Can the Water Retained in a Pulp Serve as a Criterion for.
> Skark, E. W. L.: Papierfabr., Vol. 11, pp. 1381–9, 1417–25; C. A., Vol. 8, p. 1502.

Beating, Determining the Degree of.
    Skark, E. W. L.: Papierfabr., Vol. 19, No. 23, pp. 569–76, June 10, 1921.
Beating of Paper Pulp, New Process for Determining the Degree of.
    Skark, E. W. L.: Papierfabr., Spec. No., 1914, pp. 87–92, Vol. 12,
    pp. 743–7; C. A., Vol. 8, p. 3117; Papierfabr., Vol. 20, No. 25, pp.
    845–52, June 25, 1922; Paper Trade J., Vol. 75, No. 21, pp. 53–5,
    Nov. 23, 1922.
Beating Tests.
    Sutermeister, E.: Paper, Vol. 23, No. 14, pp. 11–3, Dec. 11, 1918;
    P. P. Mag. Can., Vol. 17, No. 3, pp. 47–9, Jan. 16, 1919; C. A.,
    Vol. 13, p. 260.
Beating Tests for Papermaking Fibers.
    Sutermeister, E.: Paper, Vol. 17, No. 9, pp. 11–8, Nov. 10, 1915;
    C. A., Vol. 10, p. 525.
Beating, Sizing, and Loading.
    Teren, George: Paper Ind., Vol. 3, pp. 710–13,1921; C. A., Vol. 15, p. 4050.
Beating, Theory and Practice of, Remarks on.
    Beadle, Clayton: Papierfabr., Vol. 10, No. 49, pp. 1393–9, Dec. 6,
    1912.
Beating, Power Consumption in.
    Beadle, Clayton: Paper, Vol. 10, No. 1, pp. 15–18, 34, Dec. 18, 1912.
Beating, Today and Tomorrow.
    Campbell, W. B.: Paper, Vol. 27, No. 25, pp. 25–6, 32, Feb. 23, 1921;
    Paper Maker, Vol. 62, No. 1, pp. 37, 39, July, 1921; P. P. Mag.
    Can., Vol. 19, No. 3, pp. 65–67, 1921.
Beating and Hydration.
    Cyster, F.: World's Paper Trade Rev., July 16, 1915; Paper, Vol. 16,
    No. 22, pp. 13–4, Aug. 11, 1915; C. A., Vol. 9, p. 3129.
Beating, Some Methods for the Study of.
    Green, Arthur B.: Paper, Vol. 17, No. 24, pp. 21–8, 1916; C. A., Vol.
    10, p. 1432.
Beating, Viscosity Principle in.
    Green, Arthur B.: Paper, Vol. 21, No. 7, pp. 17, 34, Oct. 24, 1917.
Beating of Sulphite Pulp, Experiments in the.
    Kress, Otto, and McNaughton, G. C.: Paper, Vol. 20, No. 17, pp. 13–7,
    July 4, 1917; C. A., Vol. 11, p. 2542.
Beating Problems.
    Leicester, Sheldon: World's Paper Trade Rev., Vol. 77, No. 14, pp.
    1066–8, Apr. 7, 1922.
Beating, the Time of, Effect of Certain Chemicals on.
    Mansfield, E. K., and Stephenson, J. N.: P. P. Mag. Can., Vol. 14,
    No. 19, pp. 325–7, Oct. 1, 1916; Paper, Vol. 19, No. 8, pp. 17–9,
    Nov. 1, 1916; C. A., Vol. 11, p. 887.
Beating Conditions as Affected by the Temperature of the Water.
    Hatch, R. S.: Paper, Vol. 19, No. 20, pp. 18–9, Jan. 24, 1917.
Beating Engine, Theory of the.
    Haussner, Alfred: Papierfabr. Spec. No., 1913, pp. 46–51; C. A.,
    Vol. 7, p. 3839.
Beating Requirements for Cigarette Paper (see Cigarette Paper).

Beater, The Story of the.
    Wheelwright, Wm. Bond: Alfelco Facts, Vol. 1, No. 3, pp. 5–14, 1922.
Beater, The Action of the, in Papermaking.
    Smith, Sigurd: Paper Trade J., Vol. 75, No. 26, pp. 47–8, Dec. 28, 1922;
    Vol. 76, No. 1, pp. 49–53, Jan. 4, 1923; World's Paper Trade Rev.,
    Vol. 78, No. 21, pp. 1705–6, 1708, 1710, No. 22, pp. 1810, 12, 14,
    16, Nov. 24, Dec. 1, 1922.
Beater, The, in Great Britain from the Engineering Point of View.
    Nuttall, T. D.: Proc. Tech. Sec., Great Britain, Vol. 1, No. 2, pp. 180–5,
    Aug., 1921; Paper Trade J., Vol. 74, No. 6, pp. 48–9, Feb. 9,
    1922·
Beater, New Niagara, Development of the.
    Burns, W. H.: Paper, Vol. 27, No. 19, pp. 13–4, Jan. 12, 1922.
Beater Consistency Changes, A Study of.
    Gesell, W. H., and Minor, Jessie E.: Paper, Vol. 24, pp. 443–7, 1919;
    C. A., Vol. 13, p. 1765.
Beater Furnish, Report of Committee on.
    Miller, H. F.: Paper Trade J., Vol. 74, No. 23, pp. 48–50, June 8, 1922;
    Paper, Vol. 30, No. 20, pp. 7–10, July 19, 1922; Paper Mill, Vol.
    45, No. 21, pp. 14, 16, 78, June 3, 1922.
Beater Sizing, Function of Starch in.
    Traquair, John: Paper, Vol. 21, No. 23, pp. 68, 70, Feb. 13, 1918.
Beater Room, Management in the.
    Green, Arthur B.: Paper, Vol. 19, No. 23, pp. 19, 20, 22, 24, 26, 28, 30,
    32, 34, 36, 38, 40, 54, Feb. 14, 1917.
Beaters, Notes on the Efficiency of.
    Schlick, Leo: Paper, Vol. 15, No. 14, pp. 18–21, 38, Dec. 16, 1914;
    P. P. Mag. Can., Vol. 12, No. 22, pp. 647–52, Nov. 15, 1914.
Beaters, Power Consumption of, Calculating the.
    Bouvier, F. M.: Moniteur de la Papeterie Francaise, Vol. 52, pp. 788–
    790, Dec. 15, 1922; Paper Trade J., Vol. 74, No. 13, pp. 45–6, Mar. 30,
    1922; Zellstoff. u. Papier, Vol. 2, No. 2, pp. 37–40, Feb., 1922.
Beaters, Roll Pressure of, Standardization and Measurement of the.
    Muller, ———: Zellstoff u. Papier, Vol. 2, No. 1, p. 22, Jan., 1922;
    P. P. Mag. Can., Vol. 20, p. 564, July 6, 1922.
Beater? Why is a.
    Schlick, Leo: P. P. Mag. Can., Vol. 17, pp. 1024–5.
Cellulose, Colloidal Properties of.
    Minor, Jessie E.: Paper, Vol. 25, No. 14, pp. 700–3, 1919; C. A., Vol. 14,
    p. 344.
Cellulose, The Constitution of.
    Gesell, W. H., and Minor, Jessie E.: Paper, Vol. 24, pp. 527–9, 1919;
    C. A., Vol. 13, p. 1925.
Cellulose, Cotton, Action of Water and Alkali upon.
    Schwalbe, Carl G., and Robinoff, Michael: Z. angew. Chem., Vol. 24,
    pp. 256–8; C. A., Vol. 5, p. 1838.
Cellulose, Reactions of.
    Seibert, Florence B., and Minor, Jessie E.: Paper, Vol. 24, No. 23, pp.
    1007–12, Aug. 13, 1919; C. A., Vol. 13, p. 2440.

Cellulose, Contribution to the Knowledge of.   Hydrocellulose.
  Jentgen, H.: Z. angew. Chem., Vol. 23, pp. 1541–6; Vol. 24, pp. 11–2;
      C. A., Vol. 5, pp. 1187, 1677.
Cellulose Hydrate—A Contribution to the Knowledge of the Decomposition
      of Mordanting Salts by Cellulose.
  Schwalbe, Carl G.: Z. angew. Chem., Vol. 32, I, pp. 355–7, 1919;
      C. A., Vol. 14, p. 1437.
Cellulose, Hydration of, During Beating.
  Briggs, J. F.: Papierfabr., Special No., 1910, pp. 46–9.
Cellulose Mucilage.
  Minor, Jessie E.: J. Ind. Eng. Chem., Vol. 13, pp. 131–3, 1921; C. A.,
      Vol. 15, p. 1212.
Cellulose Mucilage, Study of.
  Schwalbe, Carl, and Becker, Ernst: Z. angew. Chem., Vol. 32, I, pp.
      265–9, 1919; Vol. 33, I, pp. 57–8, 1920; C. A., Vol. 14, pp. 837, 3790,
      3528.
Chemistry, Fundamental, in Paper Making, with a Note on the Chemistry
      of the Beating Process.
  MacDonald, J. L. A.: World's Paper Trade Rev., Vol. 76, Nos. 13, 14,
      1921; Chem. Trade J., Vol. 69, pp. 397–9, 1921; P. P. Mag. Can.,
      Vol. 19, No. 42, 1067–9, Oct. 20, 1921; Paper Mill, Vol. 44, No. 46,
      pp. 18, 20, 90, Nov. 5, 1921; Proc. Tech. Sec., Great Britain, Vol. 2,
      No. 2, pp. 132–42, Mar., 1922.
Cigarette Paper, Beating Requirements for.
  Paper, Vol. 23, No. 20, pp. 11–3, Jan. 22, 1919.
Colloid Chemistry and Papermaking.
  Rohland, P.: Wochbl. Papierfabr., Vol. 44, pp. 2075–7; Paper Maker,
      Vol. 46, No. 5, p. 762, Nov., 1913; Paper, Vol. 12, No. 11, p. 21,
      Aug. 27, 1913; P. P. Mag. Can., Vol. 12, No. 2, p. 45, Jan. 15, 1914.
Colloidal Chemistry as Applied to the Paper Industry.
  Darrah, W. A.: Paper Ind., Vol. 1, No. 12, pp. 1137–41, 1160–9, Mar.,
      1920.
Colloidal Chemistry in Papermaking, The Function of.
  DeCew, Judson A.: J. S. C. I., Vol. 36, pp. 357–9, 1917; Paper, Vol. 20,
      No. 11, pp. 13–5, May 23, 1917; Paper Maker, Int. No., 1916–1917,
      pp. 44–5, 47; Sci. Am. Sup., Vol. 84, pp. 191–2, Sept. 22, 1917; C. A.,
      Vol. 11, p. 1901.
Colloidal Chemistry in Papermaking.
  Bovard, W. M.: Paper, Vol. 22, No. 3, pp. 11–6; P. P. Mag. Can., Vol.
      16, pp. 729–31, 740, 751, 766, Aug. 15, 22, 1918; C. A., Vol. 12,
      p. 1251.
Consistency of Stock and White Water, Relation between the, on Paper
      Machines.
  Trimbey, Edward J.: P. P. Mag. Can., Vol. 13, No. 2, pp. 34–7,
      Jan. 15, 1915.
Density of Pulp and its Relation to the Beater.
  Paper Trade J., Vol. 60, No. 10, p. 52, Mar. 11, 1915; P. P. Mag. Can.,
      Vol. 13, No. 7, p. 206, Apr. 1, 1915; Paper Maker, Vol. 50, No. 2,
      p. 188, Aug., 1915.

Freeness Testing of Pulp.
　　Williams, F. M.: Paper Trade J., Vol. 74, No. 23, pp. 43–4, June 8,
　　　　1922; Paper Mill, Vol. 45, No. 21, pp. 26–7, June 3, 1922; Paper, Vol.
　　　　30, No. 19, pp. 10–11, July 12, 1922; World's Paper Trade Rev., Vol.
　　　　78, No. 3, p. 206, July 21, 1922.
[Freeness Tester] Apparatus for Determining the "Freeness" of Paper Stock.
　　Kirchner, E.: Wochbl. Papierfabr., Vol. 44, pp. 3694–7; C. A., Vol. 8,
　　　　p. 246.
Furnish to Beaters, Proper Order of Adding.
　　Sunderland, A. E.: Paper, Vol. 20, No. 4, pp. 13–6, Apr. 4, 1917;
　　　　C. A., Vol. 11, p. 1544.
"Greasy" or "Free" Stuff.
　　Kirchner, E.: Wochbl. Papierfabr., Vol. 44, pp. 3517–20; C. A., Vol. 8,
　　　　p. 246.
Hazards, Beater-Room.
　　Walker, Charles: Paper Trade J., Vol. 73, No. 14, p. 46, Oct. 6, 1921;
　　　　Paper, Vol. 29, No. 6, pp. 9–10, Oct. 12, 1921; P. P. Mag. Can.,
　　　　Vol. 20, No. 16, pp. 317–8, Apr. 20, 1922; World's Paper Trade Rev.,
　　　　Vol. 77, No. 24, p. 1876, June 16, 1922.
Heating of Stuff in the Beater.
　　World's Paper Trade Rev., Vol. 78, No. 2, p. 100, July 14, 1922; Paper
　　　　Makers' Mo. J., Vol. 60, No. 1, p. 7, Jan. 16, 1922.
Hollander, The Action of the, upon Pulp.
　　Smith, Sigurd: Papierfabr., Vol. 18, No. 32, pp. 591–4, Aug. 6, 1920.
Hollander, The Beating Process in the.
　　Sellergren, G.: Papierfabr., Vol. 18, No. 32, pp. 594–6, Aug. 6, 1920.
Hollander, Development of the.
　　Blau, Ernst: Papierfabr., Vol. 19, No. 28, pp. 721–7, No. 29, pp. 753–7,
　　　　July 15, 22, 1922.
Hollander, Rational Theory of the.
　　Smith, Sigurd: Papierfabr., Vols. 18, 19, 1920, 1921. · Reprinted as
　　　　"Die Rationelle Theorie des Ganzzeughöllanders," by Otto Elsner
　　　　Verlagsgesellschaft, 1922, 192 pp.　Arrangements have been made by
　　　　the Tech. Ass'n of Great Britain to translate the work into English.
Hollanders.
　　Panaitopol, Geo.: Wochbl. Papierfabr., Vol. 38, pp. 3736–40, Nov.,
　　　　1907; C. A., Vol. 2, p. 586.
Hollanders and their Power Consumption.
　　Pfarr, A.: Wochbl. Papierfabr., Vol. 38, pp. 3032–9, 3111–6, 3185–90,
　　　　3261–5, 1907.
Hollanders, The Theory of.
　　Kirchner, E.: Wochbl. Papierfabr., Vol. 38, pp. 3983–6, 4062–7, Dec.
　　　　14, 1907.
Hollander Beater, Consideration of the.
　　Kirchner, E.: Wochbl. Papierfabr., Vol. 49, pp. 282–3, 423–4; C. A.,
　　　　Vol. 14, p. 122.
Hollander Drives and Self-Regulation of the Hollander.
　　Stiel, Wilhelm: Wochbl. Papierfabr., Vol. 51, No. 14, pp. 993–5; No. 15,
　　　　pp. 1066–9, Apr. 10, 17, 1920.

Hollander Considerations.

    Haussner, Alfred: Wochbl. Papierfabr., Vol. 52, No. 21, pp. 1628–33, No. 27, pp. 2176–80, No. 31, pp. 2495–8, No. 33, pp. 2661–4, No. 39, pp. 3179–83, No. 44, pp. 3605–7, No. 48, pp. 3965–7, No. 49, pp. 4049–52, 1921.

Hollander Construction and its Influence upon the Beating Effect.

    Kirchner, E.: Wochbl. Papierfabr., Vol. 51, No. 23, pp. 1626–8, No. 25, pp. 1770–2, June 12, 23, 1920.

Hollander Rolls. Speed of Movement of the Pulp and Beating Efficiency of the Rolls.

    Piesslinger, Fritz: Wochbl. Papierfabr., Vol. 38, pp. 3507–10, 3585–8, Oct. 26, Nov. 2, 1907; C. A., Vol. 2, p. 585.

Hydrating Machinery for the Paper Mill.

    Bidwell, George L.: Tech. Assoc. Papers, Vol. 5, No. 1, pp. 7–8, 1922; Paper Trade J., Vol. 74, No. 15, pp. 191, 193, Apr. 13, 1922; Paper Mill, Vol. 45, No. 14, p. 54, Apr. 15, 1922; Paper, Vol. 30, No. 7, pp. 53–4, 56, Apr. 19, 1922; Paper Ind., Vol. 4, No. 1, pp. 78–80, Apr., 1922; Boxboard, Vol. 1, No. 5, pp. 16–18, May, 1922.

Hydration, Effect of, on the Retention of Stuff.

    Cyster, F.: Paper Making, Vol. 34, pp. 487–9; Paper, Vol. 15, No. 15, pp. 17, 38, Dec. 23, 1914; Paper Trade J., Vol. 59, No. 26, p. 52, Dec. 31, 1914; C. A., Vol. 9, p. 1843.

Hydration in Papermaking Processes.

    Beadle, Clayton, and Stevens, H. P.: J. S. C. I., Vol. 32, pp. 217–8; P. P. Mag. Can., Vol. 11, No. 9, pp. 295–6, May 1, 1913; Paper, Vol. 11, No. 5. pp. 19–20, Apr. 16, 1913; C. A., Vol. 7, p. 2305.

Hydration of Cellulose During Beating (see Cellulose).

Hydration of Pulp, Chemical.

    MacKay, Alfred: Paper, Vol. 29, No. 16, pp. 7–10, Dec. 21, 1921.

Hydration of Sulphite and Esparto Pulps.

    Papeterie, Vol. 43, pp. 146–9, 1921; C. A., Vol. 15, p. 1620.

Hydrocellulose.

    Schwalbe, Carl G.: Z. angew. Chem., Vol. 23, pp. 2030–1; Vol. 24, p. 12; C. A., Vol. 5, pp. 1187, 1677.

Length of Cotton and Linen Fibers, Diminution in, During the Preparation of Stuff for the Manufacture of Paper.

    Beadle, Clayton, and Stevens, H. P.: Chem. News, Vol. 96, pp. 139–40, Sept., 1907; C. A., Vol. 2, p. 586.

Mucilage of Parchment Paper Pulps.

    Seibert, Florence B., and Minor, Jessie E.: P. P. Mag. Can., Vol. 18, pp. 930–42, 1920; C. A., Vol. 15, p. 2183.

Power Consumption of Beaters.

    Schulte, H.: Zentr. Oesterr-ungar. Papierind., Vol. 28, p. 871, 1914; Paper, Vol. 15, No. 24, pp. 15–16, Jan. 27, 1915; C. A., Vol. 9, p. 1114.

Power Consumption of Beaters, Calculating the (see Beaters).

Power Consumption, Influence of, during Beating on the Strength and Ash Content of Paper.

    Fotieff, S.: Papierfabr., Vol. 11, pp. 1263–7; C. A., Vol. 8, p. 1502.

Power Consumption when Beating Half-Stuff and Whole Stuff.

Rehn, Arnold: Papierfabr., Spec. No., 1912, pp. 68–81, No. 37, pp. 1051–8. No. 38, pp. 1079–83, No. 39, pp. 1106–9, Sept. 13–27, 1922; C. A., Vol. 6, p. 2526, Vol. 7, pp. 889, 2855; P. P. Mag. Can., Vol. 11, No. 19, pp. 651–7; No. 20, pp. 680–5, Oct. 1, 15, 1913, No. 21, pp. 709–13, Nov. 1, 1913.

Safety in the Beater Room.

Drumb, Frank A.: Paper Ind., Vol. 4, No. 5, pp. 652–5, Aug., 1922.

Slowness Tester, Green's.

P. P. Mag. Can., Vol. 20, No. 36, p. 765, Sept. 7, 1922.

Soda Consumption and Time of Beating, Influence of, on Paper.

Beadle, Clayton, and Stevens, H. P.: Paper, Vol. 11, No. 2, pp. 18–22, Mar. 26, 1913; P. P. Mag. Can., Vol. 11, No. 8, pp. 256–9.

Temperature, The Influence of, on the Speed with which Water Drains from Paper Pulp.

Smith, Sigurd: Papierfabr., Vol. 17, pp. 1121–3, 1919; C. A., Vol. 14, p. 222.

Testing the Condition of Paper Stuff.

Klemm, Paul: Wochbl. Papierfabr., Vol. 38, pp. 3822–32, 3986–7, 1907; C. A., Vol. 2, p. 588.

Tester, Schubert's, for the Degree of Beating.

Zellstoff u. Papier, Vol. 1, pp. 21–3, 1921; C. A., Vol. 15, p. 3395.

BEATING AND REFINING

EXAMINATION QUESTIONS

(1) What is the purpose of beating?

(2) Name the principal parts of the modern Hollander.

(3) How is the batch system of operating beaters converted into continuous operation for the paper machine?

(4) Make a pencil sketch of a pulp mixer and explain how it works.

(5) (*a*) What should be the size of a stuff chest? (*b*) What are the principal requirements of a good stuff chest?

(6) If the stuff in a Jordan chest is of 3% consistency and its weight is taken as 62.5 lb. per cu. ft., at how many revolutions per minute must the crank shaft of a single-acting, simplex pump turn to throw 1 ton (2000 lb.) of bone-dry stock per hour, allowing 10% for leakage in the pump? The diameter of the pump cylinder is 8 in. and its stroke is 12 in. Ans. 63 r.p.m.

(7) (*a*) How can uniformity of consistency be obtained when furnishing beaters? (*b*) Of what benefit is it to secure this uniformity?

(8) What should be done with the beaters and Jordans in case of interruption of power?

(9) State the usual order of furnishing the beater.

(10) Define: (*a*) bed-plate; (*b*) back-fall; (*c*) lighter; (*d*) free stock; (*e*) slow stock; (*f*) hydration.

(11) Describe some changes in the fiber as the beating proceeds.

(12) Do you think any type of refiner that is described in this Section can perform all the functions of a beater? Explain your answer.

(13) A certain beater has a capacity of 420 cu. ft. (*a*) If filled with stuff at 5% consistency, how many pounds of bone-dry fiber

will it hold? (b) How many pounds of wet laps of pulp, 30% bone dry, must be used to fill this beater to the above consistency? (c) How many pounds of water must be added with the laps of pulp? Assume that both the stuff and the wet laps weigh 62.5 lb. per cu. ft.

Ans. $\begin{cases} (a) \ 1181.25 \text{ lb.} \\ (b) \ 3937.5 \ \text{ lb.} \\ (c) \ 22312.5 \text{ lb.} \end{cases}$

SECTION 4

LOADING AND ENGINE SIZING

(PART 1)

By Ross Campbell, B. S.

LOADING

FILLERS

1. Why Paper Contains Substances Other than Fiber.—Fiber is, of course, the chief constituent of all paper. If, however, fiber were the only substance entering into its composition, the usefulness of paper would be very much restricted, as the sheet would be soft, of a yellowish color, and could not be written on with a pen; printing ink would not "take well" on it. If the sheet were thin, it would be so transparent that words written or printed on one side of it could be read through the sheet. An example of paper made of especially pure fiber is filter paper. It is necessary, then, to add many other substances to the fiber to produce paper suited to the many uses to which it is put; and among these substances are *sizing, coloring,* and *fillers* or *loading.* (**Loading** properly means the adding of a filler, but the term is also applied to the substances added.) If a sheet were made in the same manner as the average book paper, but without adding a filler, it would be found to be more translucent; *i.e.,* the printed letter would show through, and it would not, as a rule, take fine line cuts as clearly as it would if a filler had been added. The principal features in connection with the use of fillers will be treated in this Section.

2. What Fillers Are and Why They are Used.—All fillers are mineral substances: they may be (*a*) a natural product, as talc, which is merely a particular kind of rock, properly ground and bolted (screened); or (*b*) a manufactured article, as crown filler. Many substances used as fillers are also used for coating paper and boards; this latter use is not considered in the Section.

Although it usually has the effect of making paper less costly, filler is not, in general, added to paper for the purpose of cheapening it; its primary purpose is to secure qualities not otherwise obtainable. The largest quantities of filler are probably used in book papers, where it is desired to produce an opaque sheet that has good ink-absorbing properties and a very smooth and even surface for taking half-tone cuts; in this case, the presence of filler improves the surface, especially when the paper is super-calendered. The filler occupies the spaces between the fibers, so that the whole surface gets approximately the same pressure and friction from the calender. In papers of this kind, the amounts of filler added to the beaters vary from 5% to 40% for clay, and 5% to 20% for talc and agalite; the average is 10% to 15% for all kinds of fillers. In the case of papeteries, where a very high color and delicate tints are frequently desired, a filling or loading substance, as crown filler, having a higher color than the stock, is of very great use. Many special industrial papers must be loaded, some of them very heavily, in order to fulfill their special requirements; as an example, stereo-matrix board may be mentioned. In practice, this latter is built up by pasting several sheets together, the whole being then covered by a special and very tough tissue paper. On this, an impression is made from type already cast by the linotype or otherwise composed. After the impression is made, the **matrix,** as it is then called, is used as a mold for casting type to fit the rotary printing presses. In order to take a good impression without breaking, and to give a good cast, it is requisite that the board be properly loaded.

In general, the presence of filler tends to decrease the strength and size-fastness of a sheet; but this effect is not sufficiently marked to be of commercial importance, unless the amount of filler used be large. If the strength of paper is specified, proper selection and treatment of the fiber must be observed. Size-fastness has not the same significance in printing papers as in writings, because printing inks have an oily medium.

3. Names of Fillers.—There are comparatively few fillers in use in the paper industry in America. Those commonly met with are: *clay, talc, agalite, crown filler*, and *pearl filler*. For special purposes, small quantities of *barytes* (barium sulphate), *satin white*, or *chalk* are used. The following table gives the name, chemical formula, approximate composition, and principal uses for fillers commonly used in the paper industry:

PAPER FILLERS

Name	Formula	Analysis (approximate)	Use
NATURAL FILLERS: 1. China clay (kaolin).........	$H_4Al_2Si_2O_9$	46% SiO_2 40% Al_2O_3 14% H_2O	(1) Book (2) Coating (3) Lower-grade writings
2. Talc......................	$_2Mg_3(SiO_3)_4$	63% SiO_2 32% MgO 5% H_2O	(1) Lower-grade writings (2) Book
3. Agalite....................	$H_2Mg_3(SiO_3)_4$	63% SiO_2 32% MgO 5% H_2O	Same as talc
4. Pearl filler (terra alba)......	$CaSO_4$	....	(1) Lower-grade writings
5. Barytes (heavy spar).......	$BaSO_4$	.. ..	(1) Coatings (2) Litho papers (chiefly abroad) (3) Photographic
6. Chalk.....................	$CaCO_3$	....	(1) Cigarette
ARTIFICIAL FILLERS: 1. Crown filler (pearl hardening)....................	$CaSO_4 \cdot 2H_2O$	....	(1) Writings (2) Superfines
2. Calcium carbonate.........	$CaCO_3$	....	(1) Cigarette
3. Blanc fixe (artificial heavy spar, permanent white)....	$BaSO_4$	....	(1) Coating (2) Litho papers (chiefly abroad) (3) Photographic
4. Satin white...............	$3CaSO_4$ $+ Al_2(OH)_3$	29% SO_3 13% Al_2O_3 39% CaO 19% loss on ignition	(1) Coating

SOURCES AND CHARACTER OF FILLERS

CLAY

4. How Produced.—**Clay,** known also as **kaolin** and **china clay,** is formed by the weathering or gradual disintegration of a certain kind of rock called *feldspar;* it is one of the most widely distributed of our minerals. In England, clay is mined by first removing the dirt, or *overburden.* A pit is dug in the center of this cleared space, and a wooden pipe is sunk in the bottom of the pit to a depth of about 100 feet. The bottom of this pipe is connected to pumping machinery. The clay is washed down the sides of the pit, around the pipe, by means of streams of water. The resulting water and clay mixture enters the central pipe by holes left for the purpose. It is then pumped through long troughs, where the heavier impurities settle out. From the troughs, it flows to settling tanks, where the water is drawn off as the clay settles, until the remaining mass is pasty. This is dug out and is taken to the drying shed. After drying, the clay is ready for shipment.

In America, the first steps in mining clay are different, two methods being used: (*a*) the open-cut method, in which the overburden is first removed, and the clay is dug out and shoveled into small cars; (*b*) the shaft method, in which a shaft, usually vertical, is sunk, and the clay is mined and hoisted to the surface.

Regardless of the method employed in mining, the clay is then broken up in water; after which, it flows through a sand box and sand and mica troughs, to remove the heavy impurities. It is then screened through either stationary or shaking screens; after which, it is filter-pressed and dried. This wet method has been displaced by a dry method in some mines. In the latter case, the clay is taken direct from the mine to the drying shed. As soon as it is sufficiently dried, it is ground, and is then freed from heavy impurities by air separation. (See Fig. 3.)

Much of the southern sedimentary clay is not purified. It is mined, dried in open sheds by exposure to the air, and is shipped as crude domestic clay.

5. Impurities in Clay.—As would naturally be expected from its origin, the chief impurities in clay from a paper-making standpoint are *grit* and *iron.* The presence of an excess of iron results in a yellowish color, which, when not too deep, is sometimes

corrected by the use of a blue dye. English clays, for example, are sometimes tinted with ultramarine, to neutralize the yellowish color. The presence of grit is objectionable because of the wearing action on the paper-machine parts; it dulls the cutter knives, causes holes in the finished paper, and creates excessive wear on the printing plates. Some American clays are reddish-yellow when wet, but are white when dry; this is not an objectionable feature in paper making, since the color when dry should be the controlling factor.

It is widely believed that for other reasons besides color, English clays are superior to those found here in America; it is generally held that the desired qualities of finish, feel, opacity, and ink-absorbing power cannot be obtained by using domestic (American) clay alone. That there is a difference between domestic and English clays is shown by the variation in the time of slaking that characterizes the two groups. If lumps of domestic and English clay are put in a pan of water, it will be noticed that the time required for the water to disintegrate the clay lumps is much shorter for imported than for domestic clays. This difference is sometimes attributed to the fact that, while a wet process may have been used in purifying both classes. the English clay is allowed to settle and the water is then drawn off; whereas in America, filter presses are used, and the pressure employed in these presses is said to affect the speed of slaking.

6. Properties of Clay.—Chemically, clay is a hydrated aluminum silicate, containing approximately 40% Al_2O_3, 46% SiO_2, and 14 % H_2O (water). Physically, it is a yellowish to bluish-white substance, having a smooth, greasy feel, and possessing the characteristic property of making a "slip" or "slurry" on the addition of water. This slurry is merely a suspension of clay in water; but it may, at times, be almost a colloidal solution. If a sample of good English china clay be shaken or stirred with about four times its weight of water for two hours and then allowed to stand, it will be noticed that it settles very slowly. The time of stirring that is necessary will vary somewhat with the clay used. Talc or agalite when treated in the same way settles very quickly.

Clay is the most finely divided of our common fillers; it has a better color than most talcs or agalites, but not as good a color as pearl or crown filler. The discoloration may be due to iron or organic matter.

7. Quantity of Clay Used in Paper.—The quantity of clay used in book paper, which is the grade in which the greatest tonnage is used, is generally from 10% to 20% of the weight of the paper, although as much as 40% is sometimes found in papers that are to be given a very high finish, in order to take fine line-cuts or half-tone prints; smaller amounts, from 5% to 10%, are used in cheap writings, tablets, etc. Up to 5% is sometimes used in newsprint.

8. Methods of Handling.—Before clay is added to the beater, it is usually made up with water (1 to $2\frac{1}{2}$ pounds of clay per gallon) and screened to remove dirt. Sometimes $\frac{1}{4}$% to $\frac{1}{2}$% of sodium
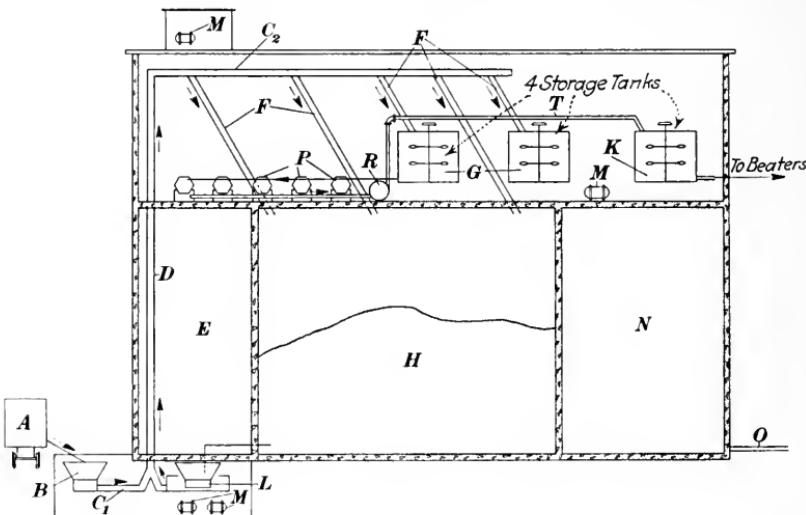
FIG. 1.

Legend: A, car; B, crusher; C_1 and C_2, spiral (worm) conveyors; D, bucket elevator; E, stairway; F, chutes to bins and tanks; G, mixing tanks; H, two storage bins, with spiral conveyor in the center of the bottom of each; K, 4 clay-milk storage tanks; L, automatic weighing hoppers; M, motors; N, alum and size house; O, platform; P, revolving screens; R, pump; T, pipe line to storage tanks.

silicate (based on the weight of clay used) is added when mixing with water; this is said to reduce greatly the viscosity of the solution, thus making the screening easier. Other alkalis, as caustic soda, bring about a similar result. Care must be exercised in the use of such substances, because of possible undesired effects on other materials, as size and coloring.

9. There are many ways of handling clay; sketches of two arrangements are given herewith. The first of these, outlined in Fig. 1, gives the course of the filler from railroad car to the storage tanks for the clay-and-water slip (slurry). The numbers refer

to the order or sequence of operations and the letters to the cut (illustration). 1, clay is transferred from cars A to a receiving hopper; 2, to crusher B; 3, to elevator feeder C_1; 4, to bucket elevator D; 5, to distributing conveyor C_2; 6, to bins H; 7, to reclaiming conveyor; 8, to scale hopper L; 9, to bucket elevator, as in D; 10, to distributing conveyor; 11, to mixing tanks G; 12, to revolving sifter screens P; 13, to storage tanks K.

10. A much simpler system is shown in Fig. 2. In this case, the clay (received in bulk) in cars A is shoveled into a chute B, which deposits it on a conveyor C. By this means, it is distrib-
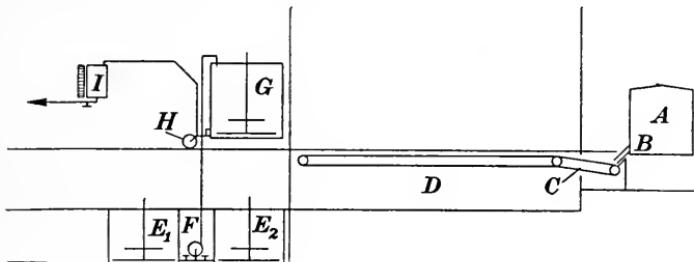
Fig. 2.

uted to any part of the clay storage bin D. As needed, clay is drawn from storage in carts, and is mixed with water in tanks E_1 and E_2. Each of these tanks should hold at least a 12-hour's supply. The agitators in these tanks should run at about 8 r.p.m.; they should pass close enough to the bottom to keep the clay thoroughly stirred up. Water is run in fast, and the agitator started; then the clay is added, gradually. From the mixers, the clay-milk is pumped to storage tanks G, and from thence to the measuring tanks I, there being one of the latter for every set of beaters. By placing tank G on a higher level, the clay slurry can be run by gravity to I, and from the latter to the beaters.

TALC

11. Occurrence.—The largest deposits of **talc** are in Vermont and northern New York. There are a number of varieties of talc, several sometimes occurring together; they differ from one another in color, hardness, and crystalline form, which accounts for the non-uniformity observed in the appearance of talcs when examined under the microscope. In some cases, each variety is mined separately, but more often as they occur, without separa-
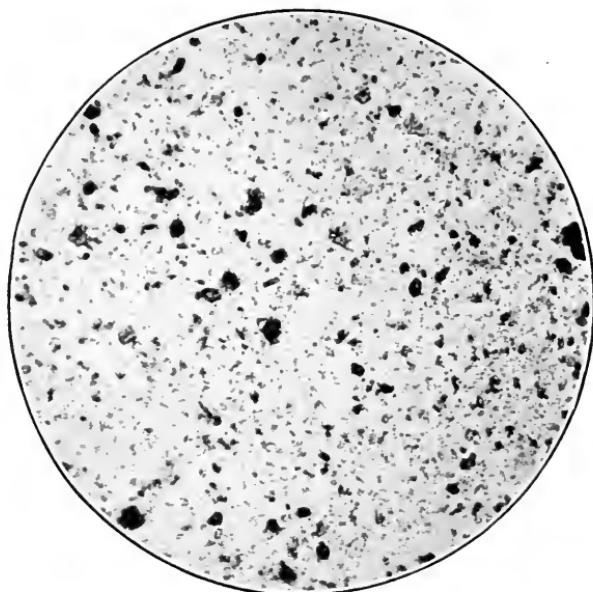
Fig. 3.

Fig. 4.
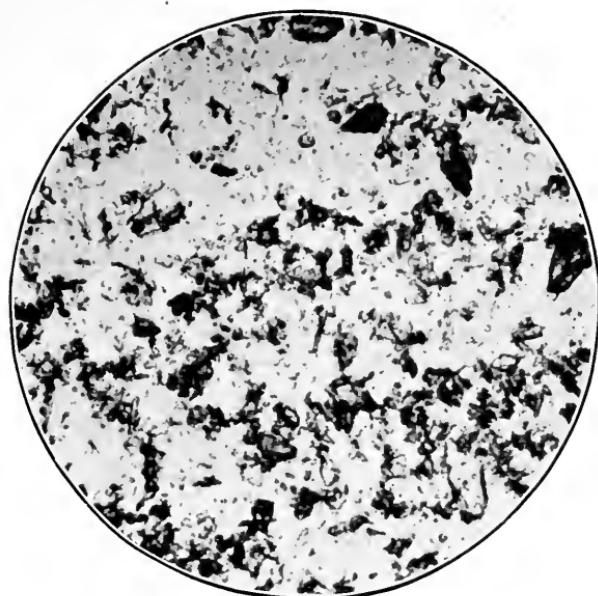
Fig. 5.
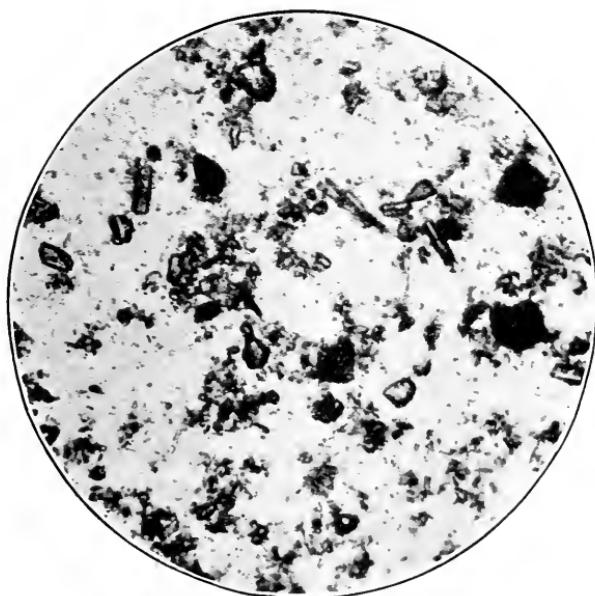
Fig. 6.

tion.   In the early days of the industry, some surface mining was done; but the work is almost wholly underground now.

12. Treatment.—After the rock is brought to the surface, it is sorted, broken in a jaw crusher, then between rolls, and is then finally ground in a roller mill, a tube mill, or in an intermittent-operating pebble mill.   The finished product is screened only, or is air-separated, depending on the degree of fineness required. Under the microscope, it is generally seen as flat plates of many sizes.   (See Fig. 5.)

13. Properties.—Chemically, talc is a hydrated magnesium silicate, giving by analysis approximately 32% MgO, 63% SiO$_2$, and 5% H$_2$O (water).   Physically, it is a greenish-gray substance having a soapy feel.   Soapstone is a variety of talc.

14. Uses.—Talc is one of the natural fillers; it is much used in book papers, particularly those which are not to be used for fine printing, as line cuts, half-tones and other delicate plates.   It is not suited to the latter, because the comparatively sharp, hard particles of talc are large enough to wear the printing plates badly, thus causing fine lines to blur.   The use of talc tends to soften the sheet and improve the printing qualities, but to a less degree than does clay.   To a certain extent, a shiny appearance and a slippery feel is given the paper.   It is generally used in smaller quantities than clay, from 3% to 20%, averaging 10%.

The objections to its use are the possibility of the presence of grit, "shiners" (pieces of mica), carbonates, and iron.   On the other hand, talc is cheaper than clay, has a higher retention (see Art. **23**), and it can be added to the beater dry, as received; whereas clay must be carefully mixed with water before adding. Probably its most desirable use is to soften the cheaper writing, tablet, papeterie, and similar papers, in which it is used in quantities of from 3% to 10%.   It serves to remove that "woody" feel to some extent.   Its color is, in general, poorer and less satisfactory than any of the other fillers.

OTHER FILLERS

15. Agalite.—In many ways, agalite is similar to talc; chemically, it is identical with talc.   Physically, it is less soapy than talc, but has much the same general color.   Under the microscope, it is supposed to appear as long needle-like crystals.   A careful examination of many commercial samples of talc and

agalite has shown that these substances grade into each other as regards crystal form.

The properties of agalite, drawbacks to its use, etc. are much the same as in the case of talc, but the former is considered to be more wearing on paper-machine clothing parts and on printing plates; it tends to wear the fine lines on the latter and to fill them with dust. For this reason, it is not used to the same extent as clay or talc, especially in book papers. Agalite should not be used in quantity in papers that are to be cut or punched, because it dulls the steel cutting edges. Its color is, in general, a gray, somewhat lighter than talc, and lacks the characteristic green tint of the latter.

16. Asbestine.—Asbestine is a filler that much resembles talc and agalite; under the microscope, it appears as a mixture of these two. Its use and properties are a sort of a compromise, as would be expected from this crystal formation. (See Fig. 6.)

17. Crown Filler.—Crown filler has by far the purest white color of any of the fillers; it is also known as **pearl hardening**. Crown filler is an artificial (manufactured) product, as distinguished from clay, talc, agalite, and pearl filler, which are mined. It is made as a precipitate by the interaction of solutions of $CaCl_2$ and $NaHSO_4$. Chemically, it is calcium sulphate, with two molecules of water of crystallization $CaSO_4 \cdot 2H_2O$. The dry substance shows, on analysis, 79% $CaSO_4$ and 21% H_2O. By *water of crystallization* is meant water chemically combined, so that a substance containing it can appear to be quite dry while containing, in some cases, as much as 50% water. Crown filler appears on the market as a wet powder that contains 33% water, of which 21% is chemically combined and the remainder is mechanically mixed. (See Fig. 4.)

Owing to the methods of manufacture, crown filler can be kept free from grit and very low in iron and in acid content. Extensive mill and laboratory tests have shown that free acid, figured as hydrochloric acid, should not be over 0.05%, based on the sample as received; more than this may cause trouble with the rosin sizing. It is the most soluble of the fillers, about 30 pounds being dissolved in 1000 gallons of pure water at ordinary room temperature. At this rate, from 60 to 80 pounds are dissolved in the water contained in an ordinary 1000-pound beater; therefore, if less than 10 pounds of crown filler per 100 pounds of fiber

are added to the beater, almost no calcium sulphate is found in the furnished paper. The solubility is less when hard water is used, and it is decreased by the addition of alum. The quantities of crown filler used are generally 40% to 50% of the fiber furnish.

This filler is particularly useful in high-grade papeteries, where a high white color or delicate tints are desired. As it is the most expensive of the fillers and has the lowest retention, its use is necessarily confined to the better grades of paper. When present, it interferes somewhat with the rosin sizing of the sheet, because, owing to its solubility, enough calcium sulphate is in the solution to react with the rosin size, precipitating a calcium resinate, or calcium soap, which has no sizing value. A similar effect on sizing is observed when very hard water is used.

18. Pearl Filler.—Chemically, **pearl filler** is the same as crown filler, except that there is no water of crystallization and only about 1% of mechanical water. It is found in nature, as are talc and agalite, and has merely to be ground and sifted to prepare it for use. The alkalinity is about the same as talc, 1% to 2%, figured as $CaCO_3$, and the grit is less. In color, it is not equal to crown filler, but it is far better than in any of the other fillers. It is less expensive than crown filler and its retention is greater. The chief reason for its greater retention is that of each 100 pounds of crown filler added to the beater, 33 pounds is water, while pearl filler is almost free from water. Pearl filler is used chiefly in medium-grade papeteries and writings, and it is added to the beater dry.

FILLERS FOR SPECIAL PAPERS

19. Chalk.—In addition to those already described, a number of other fillers are used for very special papers. **Chalk** (the ground mineral), or calcium carbonate (precipitated for this purpose), is used in amounts as high as 30% in cigarette paper. Its use speeds up the burning of the paper, because, when the paper is heated, carbon dioxide gas is given off; this opens the pores of the paper and promotes combustion. Chalk also improves the color of the ash.

20. Barytes.—**Barytes,** or **barium sulphate,** is used in photographic papers on account of the special surface imparted to the sheet; it is quite expensive, and its retention is low because of its weight. It is also used in some special printing papers that must be very flat, it being held that the weight of the filler holds

the paper down. This filler is usually prepared by adding a soluble sulphate to a solution of barium chloride.

21. Oxide of Iron and Wilkinite.—Oxide of iron is sometimes used to color leather board and box board, and to act as a filler at the same time. This material is said to give trouble, however, due to the pitting of press and calender rolls; this effect is especially to be noted on the latter, if a water finish is being applied.

Recently, work has been done on a very highly colloidal, clayey substance that is known to the trade as **wilkinite,** geologically called bentonite. This material appears to have the property of retarding the settling of clay suspensions. The indications are that it will also increase the retention of filler in paper.

22. The Microscopic Appearance of Fillers.—In Figs. 3, 4, 5, and 6, are shown photomicrographs of four commonly used fillers. These were prepared by the Paper Section, Bureau of Standards (United States). They show the marked difference between the finely divided, colloidal clay and the highly crystalline crown filler; also, the similarity between talc and asbestine. A few of the needle-shaped crystals are visible, especially in the asbestine. The magnification in each case was 100 diameters.

RETENTION OF FILLERS

23. Per Cent of Retention.—By retention of filler is meant the pounds of filler found in the paper for each 100 pounds of filler added to the beater. To find the per cent retention, divide the weight of the filler in the paper by the weight of filler added to beater and multiply by 100; thus,

$$\text{per cent retention} = \frac{\text{weight of filler in paper}}{\text{weight of filler in beater}} \times 100$$

Instead of using the weights of filler, the percentage of filler by weight may be used, in which case, care must be taken in calculating retention that the per cent filler in the beater and that in the finished paper are figured on the same basis, which should be the weight of bone-dry fiber. Proper corrections should be made for the moisture content of the original filler and of the filler as it occurs in the paper, for the ash content of the fiber furnish, etc. Some fillers contain water of constitution (part of the molecule), besides moisture held mechanically; all this water is lost in determining the ash content. The particular formula to be used in any given case should be picked out after considering the

accuracy of the final result that is desired. This matter is treated at length in the Section on *Paper Testing*, Vol.V. The per cent retention of the filler, as determined by the amount and character of the ash, is used in calculating the amount of filler that must be added to the stock. Allowance must be made for the solubility of the filler in some cases.

When waste paper from the mill is used, especially "broke" (spoiled paper), consideration must be given to any filler that may be contained in it. It will be seen, too, that any filler contained in white water that may be used in the beater or on the machine, will affect the retention of the filler added; this water may become saturated, so to speak, with filler.

24. Conditions Affecting Retention.—The retention of any given filler will vary widely, according to stock and machine conditions. Other things being equal, retention increases as the weight of the sheet, the slowness (hydration) of the stock, or as the length of the fiber increases. It decreases as the speed of the machine increases, and as the amount of suction on boxes and rolls increases. Retention is greater in a well-sized sheet than in a slack-sized sheet; with mechanical and sulphite pulps, it seems to decrease with the length of fiber. Other conditions being the same, but using different fillers, the retention increases as the size of the filler particles increases, and as the specific gravity or weight per cubic foot decreases. Retention decreases as the solubility and moisture content of the filler increases. Other conditions affecting retention are the amount of shake of the machine, and the quantity of fresh water or of white water used. The retention is less than the normal by from 10% to 20%, if the amount of filler added is less than about 5% or greater than 30% of the weight of the fiber; this last does not apply to crown filler, which reaches its maximum retention with additions of 50% to 60%, nor to pearl filler.

Unfortunately, little retention data for pearl filler are available. It seems, however, that the ratio of bone-dry calcium sulphate, with no water of crystallization retained, to bone-dry calcium sulphate added, is approximately the same for both crown and pearl fillers, when large amounts are used. Crown filler usually contains about 33% of water whereas pearl filler contains almost none at all. If the retention is based on the actual pounds of filler added, irrespective of moisture content, the retention of pearl filler would be about half again as great as that of crown filler.

25. Some Retention Data.—The following data are based on papers having a folio weight (standard substance number or weight per ream of 500 sheets, 17 inches × 22 inches) of about 20 pounds, an addition of filler of 10% to 20%, and a machine speed of 100 to 200 ft. per min. The figures are average results; the papers were writings and envelopes, with a few book papers. The retention to be expected in book paper of medium weight is about
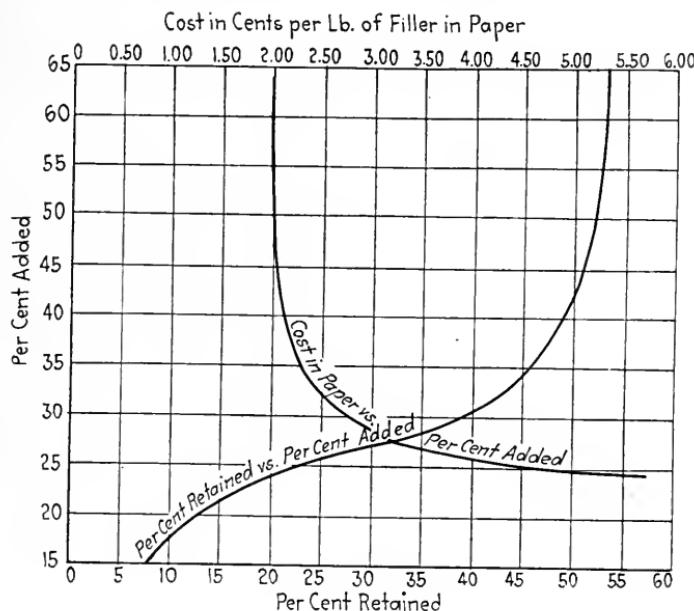
FIG. 7.

10% lower than the figures obtained, which were: talc, 82%; agalite, 75%; clay, 70%.

For crown filler, the following figures for the same sheet weight and range of machine speed are given. The papers were writings and papeteries.[1]

PER CENT ADDED (POUNDS PER 100 POUNDS OF PULP)	PER CENT RETAINED (BASED ON FILLER ADDED)
10	0.0
20	13.5
30	39.5
40	49.0
50	52.0
60	53.0

[1] Papers for fancy correspondence boxes, and the like.

26. In Fig. 7, a curve is given of the retention of crown filler, showing how this varies with the amount added. Another curve is also given, which shows the variation in the cost per pound of filler in the paper with the amount added to the beater; the rapid increase in cost when small amounts are added is very evident, and is due to the large percentage lost. The cost of this filler delivered to the mill was $1.08 per 100 pounds when this cost curve was drawn.

27. Other conditions than those mentioned being constant, retention of filler will vary as follows:

RETENTION INCREASES	RETENTION DECREASES
As weight of sheet increases;	As solubility of filler increases;
As machine speed decreases;	As amount added to beater decreases below 5%;
As engine sizing changes from slack to good;	As amount added to beater increases above 30% (except crown filler).
As slowness of stock increases;	
As length of fiber increases;	
As size of filler particles increases;	
As specific gravity of filler decreases.	

28. When to Add the Filler.—The proper time for adding filler is generally thought to be as soon after "furnishing" as possible, and before the addition of size and alum, as the precipitation of size tends to fix the filler in the fiber. The usual practice is to add: first, filler; then, rosin; and, last, alum.

Retention will be increased by the use of starch or sodium silicate; but it is doubtful whether the increase warrants the use of these materials for this cause alone. Some even advocate boiling filler and starch together. It has also been recommended to mix the clay with separately boiled starch, and then add rosin size to the mixture; after which the whole is added to the beater. Unfortunately, there is little actual data available. Clay, however, should be added, and it should be thoroughly mixed with the stock, before alum is added; otherwise, the acid of the alum will destroy the colloidal properties of the clay, thereby lowering retention, giving poorer finish, etc.

QUESTIONS

(1) What substances may paper contain, other than fiber?

(2) How is clay produced? How does it differ from talc?

(3) What chemical difference is noted between crown filler and pearl filler?

(4) How is clay usually added to the beater? (b) talc?

(5) Would you expect any difference in the retention of crown filler in soft water and hard water? Explain your answer.

ANALYSIS OF FILLERS

29. Sampling.—The sampling is done by opening 5% to 10%, preferably 10%, of the barrels or packages, as received from the car, and taking a small portion of each, making the weight of the total sample about 5 pounds. In case of a shipment in bulk, it is best to take the sample at frequent and regular intervals, as the shipment is being unloaded. From a car of clay, the filler most commonly shipped in bulk, the sample thus taken should weigh about 50 pounds, and should represent both the fine and coarse portions. The lumps should be broken up and the sample quartered down, until it will about fill a Mason jar; this is kept in an air-tight container until the analysis is to be performed.

30. Preparation for Analysis.—The 5-pound sample is carefully mixed, all large lumps are broken up, and the whole is quartered down to about 50 grams. The analyst will do well at this point to determine whether the filler is clay, talc, agalite, calcium sulphate, etc. A qualitative test may also be made for acidity.

31. Moisture Content.—Mechanically combined moisture is determined on 2 grams of this sample by drying at 105°C. to a constant weight. The chemically combined moisture may be determined by placing this dried sample in a crucible and heating at the full heat of a Meker burner until a constant weight is secured; or by heating 2 grams of the original sample in the same manner, and then subtracting the mechanical (surface) moisture from the result. In the case of crown filler, the total moisture is determined by igniting a 2-gram sample over a Meker burner to constant weight; from this result, the chemically combined moisture may be calculated, the molecular formula for crown filler being $CaSO_4 \cdot 2H_2O$. Subtracting this result from the original 2 grams taken for analysis, the mechanical moisture is obtained.

32. Color.—Color is determined by comparison with a standard sample that has been selected for color. Small amounts of the sample to be compared and of the standard are pressed together on a black paper, with a polished steel spatula. Any difference in color can then be readily seen, and the sample is reported to be as good as standard, yellower, grayer, or whatever difference is observed.

33. Fineness.—Fineness may be determined microscopically, by elutriation or by the sieve method; but neither method is

applicable to calcium sulphate or other appreciably soluble fillers, because of their solubility.   Fineness is determined most simply microscopically.   A very small amount of filler is placed on a glass slide, with a small amount of water, and a cover glass is placed over the mixture.   It is examined under low power of the microscope, comparing the sample with the standard, which has been treated in the same way.   If a microscope is not available, 200 grams of clay are mixed thoroughly with 1000 c.c. of water and strained through a 200-mesh, silk, bolting cloth, by use of a gentle stream of water.   The material remaining on the screen is dried and weighed.   This will give a fair estimate of the per cent of grit present.

34. Elutriation Tests.—The elutriation test on a filler gives the per cent of grit or coarseness, but the method is very com-
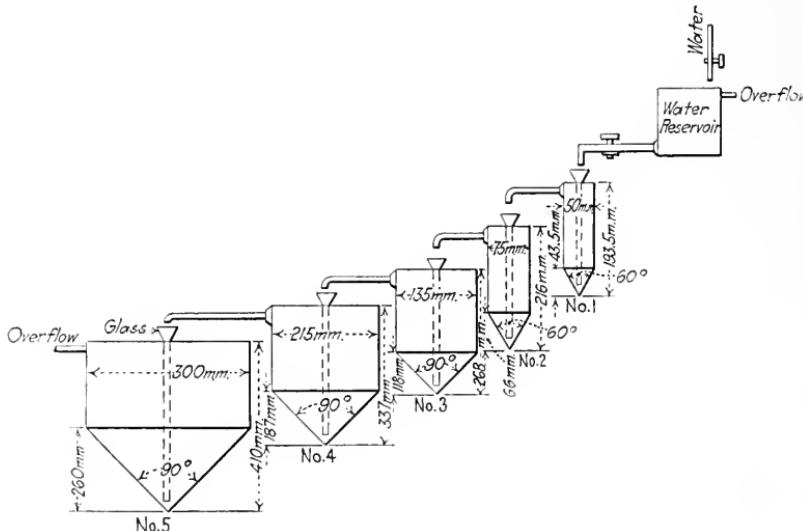
FIG. 8.

plicated; for general purposes, microscopic analysis is sufficient. Binns' apparatus is very satisfactory for a careful elutriation test, and should be used when very careful analysis is necessary. The arrangement of this apparatus is shown in Fig. 8.   In making the test, 50 grams or 100 grams of bone-dry clay are weighed out, thoroughly slaked (preferably in some sort of tumbling device in which duplicate results can be obtained), and strained through a 100-mesh sieve into No. 1 receptacle.   Water is then run in

at the rate of 2.8 c.c. per second, giving a rate of flow of 1.5, 0.7, 0.18, 0.08, and 0.04 mm. per sec. in the various receptacles, which progressively increase in size, the smallest having, of course, the highest rate of flow. The flow should be continued until the water from the last receptacle is clear; then weigh the various residues. There will probably be little or none in the first two, and it will probably be found that the residue in the third receptacle is the best measure of the fineness of the sample. There are several other types of elutriating apparatus on the market, as those of Schöne or Hilgard. This subject is very fully covered in Wiley's "Principles and Practice of Agricultural Analysis." The Schöne apparatus gives very accurate results.

35. The following method will give tests for comparing two fillers. A 10-gram sample of the filler is placed in a glass cylinder, $11\frac{3}{4}$ inches high and $1\frac{5}{8}$ inches in diameter, and which holds 400 c.c. The filler is thoroughly shaken up with a small amount of water, and the cylinder is filled to the top. From a large bottle, 58 inches above the bottom of this glass cylinder, 2500 c.c. is allowed to pass through the cylinder from a glass tube, $\frac{1}{8}$ inch in diameter, extending to the bottom of the cylinder. The residue is then filtered on a tared filter, dried, and weighed; this gives the amount of grit or coarseness in the filler. Variation in the rate of flow of the water can be made to suit special conditions. Other things being equal, the greater the rate of flow the larger the particles carried out of the cylinder, and the smaller the apparent amount of grit in the sample. The amount of grit in any filler should be less than 1.5%. When a partially soluble filler is tested, the water used must be saturated with it, and the temperature must be kept constant.

36. Sieve Test.—For the sieve test, which is not so reliable as the elutriation test, a set of standard sieves, from No. 100 to No. 325, inclusive, is recommended. These numbers have been given to a scientifically determined series and correspond approximately to the ordinary mesh. These should be small, and be light enough to permit the residue to be weighed on the sieve without transferring to tared filter paper. This method is as follows:

Place the weighed sample of clay in a beaker and add distilled water. For a 50-gram sample, add 500 c.c. of water. Let stand for one-half hour, and then agitate thoroughly, but without grinding. Let stand for a few minutes, for the coarse material

to settle in the bottom, and decant through the weighed sieve, which has been previously cleaned and dried in an oven at 105° to 110°C. Decant a small portion slowly through the screen, and wash out with water. Gradually transfer the suspended material, finally leaving the coarse particles on the sieve. With proper manipulation, a large portion of the sample will pass through the sieve during the process of transference. If the contents are dumped on the sieve at one time, the coarse particles will clog the holes, which will cause the sieving operation to prove difficult, often impossible, unless the sediment is stirred with the hand. Such hand stirring or rubbing of the material through the sieve is strongly to be condemned; it not only forces through the larger particles but it also permanently distorts the apparatus, so that the sieve is rendered worthless. Gently tap the sieve while washing under a stream of water. Toward the end, it will be found more efficient to place some water in a dish and to set the sieve in this; then, by a shaking motion, the sieve is washed from below. Such washing will remove the fine particles much more quickly than by placing water on the sieve with the residue. By having a dish painted black, the thoroughness of washing a white pigment will be apparent. Finally, heat the sieve for 1 hour at 105° to 110°C., cool, and weigh.

When properly used and cared for, sieves should be reliable for a number of years. No washers, shot, or other device for hastening the sieving process should ever be used. The following table gives the sizes of the wires and openings for standard sieves from No. 100 to No. 325.

Sieve No.	Opening in Inches	Wire Diameter, Inches
100	0.0059	0.0040
120	0.0049	0.0034
140	0.0041	0.0029
170	0.0035	0.0025
200	0.0029	0.0021
230	0.0025	0.0018
270	0.0021	0.0016
325	0.0017	0.0014

37. Alkalinity.—Alkaline fillers are likely to have an injurious effect on sizing and coloring, and where they must be used, proper precautions, such as in selecting colors, should be taken.

The alkalinity due to carbonates and bicarbonates may be determined by any of the standard methods for the determination

of carbon dioxide CO_2; that is, by treating with acid and weighing the CO_2 absorbed in KOH or soda lime. The advantage of the following method is that it does not involve the purchasing of elaborate apparatus, and it is more accurate and quick for routine work to determine small amounts volumetrically and gravimetrically.[1]

The apparatus consists of two 1000-c.c. gas-washing bottles, filled with 20% solution of NaOH for the purpose of removing CO_2 from the air. These flasks are connected to a 250-c.c. Erlenmeyer flask that is fitted with a rubber stopper, through which a dropping funnel is passed. The outlet of the Erlenmeyer flask is connected with a train, which consists of four 50-c.c. Nessler tubes, fitted up as washing bottles. The tube nearest the Erlenmeyer flask remains empty, and serves as a trap for any vapors or solid particles that may be carried over mechanically from the generating flask. The next three tubes contain exactly 25 c.c. of N/2 NaOH solution. The last tube is connected to the suction, and a constant current of air, free from CO_2, is drawn through the apparatus. In making the determination, 10 grams of filler is weighed into a mortar and triturated with two 15-c.c. portions of water. The residue is then washed into the Erlenmeyer flask, the total volume of solution being about 50 c.c. The apparatus is connected up. The pinch cocks are opened on the connection between the Erlenmeyer flask and the wash bottles on the one side, and the first and second Nessler tubes on the other side. A current of air, free from CO_2, is drawn through the apparatus at a moderate rate. During this time, the Erlenmeyer flask is shaken occasionally. In a dropping funnel 50 c.c. of a 10% alum solution is placed, the stop cock is opened, and the alum is allowed to run into the Erlenmeyer flask, care being taken that the alum does not run into the flask fast enough to force the filler emulsion backward into the wash bottles. A column of alum solution should be allowed to remain in the stem of the funnel as a seal. An hour after the alum solution is all added, the pinch cocks are closed and the suction shut off. The contents of the last three Nessler tubes are washed carefully into a flask, and are titrated with standard N/2 acid, using phenolphthalein as an indicator, until an end point is reached; then methyl orange is added,

[1] Quantitative Analysis; Treadwell and Halls Quantitative Analysis and Mahin's Quantitative Analysis are suggested as reference works on laboratory procedure and general analysis.

and the titration is completed. A blank consisting of 25 c.c. of N/2 NaOH solution is titrated with N/2 acid in the same manner. Phenolphthalein titrates one-half the carbonates present and all of the hydrates present, and methyl orange titrates the other half of the carbonates. Calculate the alkalinity in terms of calcium carbonate, by multiplying the methyl orange titration by 2 and then by 0.02504.

The alkalinity due to calcium carbonate is of chief importance in a paper filler, and should be kept under 5%. Excess alkalinity tends to kill rosin size, causes excess foam, and may alter the shade of certain dye stuffs.

38. Iron.—Take 2 grams of sample and dissolve in 10 c.c. C.P. Conc. HCl. If there is any residue, fuse it with sodium carbonate, dissolve in concentrated hydrochloric acid, and add to the main portion of the solution. Wash dissolved filler into a 100-c.c. Nessler tube, and add a few drops of a N/10 $KMnO_4$ solution, to be sure that the iron is oxidized to a ferric condition. The color of the potassium permanganate $KMnO_4$ should persist for at least two minutes. Add 10 c.c. of potassium sulphocyanide KCNS solution (2% solution), and make up to 100 c.c., mixing thoroughly. Compare immediately the resulting color with a standard that has been prepared at the same time, by adding a standard iron solution (1 c.c. = 0.00001 gram Fe_2O_3) to another Nessler tube, which contains two or three drops of $KMnO_4$ solution, 10 c.c. of KCNS solution, and 85 c.c. of H_2O, until the same color is produced in both tubes. The number of cubic centimeter of iron solution used multiplied by 5 gives the parts of Fe_2O_3 per million. Iron solution is best prepared by dissolving 1 gram of pure iron wire in a small amount of H_2SO_4, oxidizing this with N/10 $KMnO_4$, and making up to 1000 c.c. By diluting a little of this solution 100 times, a solution containing 0.00001 gram Fe_2O_3 is obtained. The amount of iron in fillers used in papermaking should be kept very low, especially in a filler partially soluble in water, as crown filler, where the iron content should not exceed 0.005%. In fillers that are insoluble in water, the presence of iron is usually detected by the high yellow color that makes them unsatisfactory for paper making.

QUESTIONS

(1) How should a sample of filler be taken and prepared for analysis?

(2) Explain the testing of a filler for alkalinity. Why is this important?

LOADING AND ENGINE SIZING

(PART 2)

By Judson A. DeCew, B. A. Sc.

ENGINE SIZING

HISTORICAL

39. Tub Sizing.—In the early days of its manufacture, when it was made by hand in small sheets, the method of rendering paper non-absorbent consisted entirely of surface sizing, which was effected by dipping the finished sheets into a solution of glue or gelatine (prepared from hides), after which the paper was air-dried. This process is known as **tub sizing,** and the size used is called **animal size.** Further details of this practice and the method of its application under modern conditions are given in the Section on *Tub Sizing ond Finishing Operations*, Vol. V. This practice continued until 1807, when rosin sizing was discovered by Maritz Illig of Erbach, Frankfort, Germany.

40. Rosin Sizing.—Briefly stated, the process of **rosin sizing** consists in adding to the stock in the beater a sufficient quantity of a soap made by cooking *rosin* (which is a mixture of organic anhydrides) with a solution of *caustic soda* or *soda ash*. When this soap, which may or may not contain rosin in excess of the amount necessary to combine with the soda, is thoroughly mixed with the stock, *alum* (aluminum sulphate) is added, either in powdered form or in solution. The alum causes the rosin to be precipitated on the fibers in the stock, together with a certain amount of aluminum hydrate. When first formed, this precipitate is gelatinous; and, when mixed with the paper stock, is spread over the individual fibers. When the stock is run on the

machine and dried, this hydrated or resinous material hardens, and forms a coating that is more or less water repellent, which completes the sizing operation. The degree to which the paper is made impervious to water depends on the amount of rosin and alum used, the physical properties of these substances when the precipitate was first formed in the beater, the kind and quantities of fiber and loading, the manner of beating, temperature of machine dryers, etc.

MATERIALS USED IN SIZING

ROSIN AND SODA ASH

41. Sources of Rosin.—Rosin is the trade (or common) name of the substance otherwise known as *colophony*, which is the residue left in the still after the distillation of the turpentine and pine pitch. **Pitch, or oleo resin** is obtained from a large number of species of pine; but the chief commercial source is the longleaf and shortleaf pine of the Southern States. These trees are tapped by cutting the bark and allowing the resin to exude and flow into cups in the form of a thick liquid, which is collected and distilled. During distillation, the turpentine distills over and is collected separately; the residue in the still is roughly filtered, while molten, and forms the rosin of commerce.

42. Grades of Rosin.—Rosin is graded into a large number of classes, according to the depth of color and the amount of impurities it contains. The grades are designated by the letters of the alphabet, those bearing the first letters of the alphabet being the lowest in quality and the darkest in color. The highest grades are WG (window glass) and WW (water white). The grades most used for paper-maker's size are F and G. The reason for this is that, although the lower grades give good water resistance, they cannot generally be used on account of the color, while those lighter than G are not hard and dense enough to give the best sizing. These grades are standard, and the rosin coming on the market in the Southern States is inspected and graded by Government Inspectors.

Quotations are made in terms of a barrel of 280 pounds, but the rosin is marketed in casks that have a gross weight (the cask and its contents) of about 500 pounds. Consequently, when purchas-

ing rosin for use in paper making, allowance must be made for waste in breaking up the containers. The weight of the staves is from 17% to 18% of the gross weight. The price of rosin fluctuates considerably, depending on the demand in various parts of the world for rosin and also on the demand for the turpentine that is produced at the same time as the rosin.

43. Characteristics and Uses of Rosin.—Chemically, rosin consists chiefly of the anhydride of abietic acid $C_{44}H_{62}O_4$. For practical purposes, however, rosin may be considered as consisting of 90% to 97% of abietic acid $C_{44}H_{64}O_5$, because the anhydride, when cooked with alkali, gives salts (or soaps) in exactly the same manner as abietic acid itself would do. One of the outstanding characteristics of soaps made from rosin is their ability to emulsify oils and like materials in water solutions. It is this property of rosin soap which makes possible the use of size solutions containing a quantity of rosin in excess of that required to combine with the soda.

Other uses for this rosin are in the manufacture of soap, linoleum, and varnishes, as raw material for the production of rosin oil, and as a constituent for various plastic compositions.

44. Extracted Rosin.—In addition to obtaining rosin direct from oleo resin, it may be obtained by extracting with solvents, such as naphtha, the resinous dead wood of the Southern pines. The rosin so obtained is called **extracted rosin,** and its composition differs from that made from pitch. When used for sizing papers, it must be handled somewhat differently also. Extracted rosin is quite free from dirt and is uniform in character; but, on account of its dark color, it is generally classed as F rosin.

About 14.5 pounds of soda ash is required to neutralize the resin acids in 100 pounds of extracted rosin; whereas, about 16 pounds of soda ash is required for 100 pounds of gum rosin.

Another class of recovered rosin is that obtained from soda liquors in the cooking of resinous woods by the soda process. This rosin is recovered in the form of soap, is dark in color, has different physical properties from ordinary rosin, and if used alone, is not an efficient sizing material.

45. Soda Ash.—Soda ash, or sodium carbonate Na_2CO_3, combines with rosin to form rosin soap. It comes on the market in two varieties, the light and the heavy, the light variety being the most convenient for the manufacture of size. Soda ash

should contain 58% of Na_2O; if any other percentage is used, allowance should be made for the difference, since only the Na_2O takes part in the reaction. In some cases, caustic soda NaOH is used in place of soda ash; it saponifies the rosin more rapidly, but it is more difficult to handle and is more expensive.

<div style="text-align:center">———</div>

<div style="text-align:center">ALUM</div>

46. Paper-Maker's Alum.—Alum is the now commonly used trade name for aluminum sulphate $Al_2(SO_4)_3 \cdot 18H_2O$, which is frequently called **paper-maker's alum.** Properly speaking, the term alum should be confined to the double salt of aluminum sulphate and potassium sulphate $Al_2(SO \cdot)_3 \cdot K_2SO_4 24H_2O$, or a similar double salt, and the first alum used in paper making was this double salt, which can be obtained in a very high degree of purity. For this reason, it is still used by some paper makers, in spite of its greater cost; although this is probably entirely unnecessary, since very pure aluminum sulphate containing 16.85% of Al_2O_3 can be obtained. A grade of aluminum sulphate is made which is practically free from iron and other impurities; but it is made by a special process, and it is expensive. The common grade of aluminum sulphate contains about 0.5% of iron, calculated as Fe_2O_3, and some alumina Al_2O_3 and silica SiO_2, none of which are sufficient in amount to be injurious to ordinary grades of paper.

47. Iron-Free Alum.—For the best grades of paper, the percentage of iron in the alum should be as low as possible. **Iron-free alum** is made from pure alumina Al_2O_3 and sulphuric acid, whereas the common grades are made by dissolving bauxite in sulphuric acid and filtering the solution from the undissolved residues. The solution is then evaporated until it is reduced to a point where the moisture present would be that represented in the formula $Al_2O_3(SO_4)_3 \cdot 18H_2O$, after which, it solidifies, and is then ground and packed for shipment.

Owing to the two distinct methods used for making the iron-free and the commercial alum, there is a decisive difference in the composition of the two products. An alum, however, having as low as 0.2% of reduced iron sulphate should be good enough in color for the best papers. Often, more damage is done to the paper from iron specks that come from the beater bars than from

the iron in the alum. Iron may show up as rust spots, or it may affect the color by reacting with the rosin or the dyestuff.

48. Basic Alumina.—Paper-maker's alum generally contains an excess of alumina Al_2O_3 over the theoretical quantity to be accounted for in the formula $Al_2O_3(SO_4)_3 \cdot 18H_2O$. This excess of alumina is called **basic alumina,** although it is undoubtedly all combined with the SO_3.

An **acid alum** is one that contains free sulphuric acid. The *free acid* is that in excess of the amount required by the alumina, iron, soda, etc. present.

The brands of aluminum sulphate on the market are generally basic to the extent of 0.15% to 1% of alumina; but, for some mill conditions, as, for instance, if hard water is used, an alum of more acid characteristics (up to 0.5% free acid) might be suitable.

49. Uniformity of Commercial Alums.—In spite of the variation and the impurities in the bauxites from which it is made, the commercial aluminum sulphate is well standardized, and it is generally very uniform in character. Aluminum sulphate was once made largely from china clay, which is a silicate of alumina that contains about 37% of Al_2O_3; but china clay does not dissolve directly in sulphuric acid, unless it is previously calcined in a very exact manner. The silicious residue that is left when alum cake is made in this way from china clay is generally removed, as it has but little value for the paper maker, except as a filler.

50. Analyses of Alum.—The following table gives characteristic analyses of alum (aluminum sulphate), compiled from several sources: the table is from Chemistry of Pulp and Paper Making, by Sutermeister.

	1	2	3	4	5	6	7	8[1]
Insoluble in water........	.....	0.49	0.06	0.67	0.18	0.4	0.16	20.0–26.5
Alumina, Al_2O_3.........	14.70	16.20	18.81	22.37	16.32	17.4	21.87	12.3–13.0[2]
Iron, Fe_2O_3.............	0.12	0.06	0.80	0.59	0.51	trace	0.40	0.1– 0.2
Zinc oxide, ZnO.........	.....	.....	.....	3.80	.....	.....	.....	....
Soda, Na_2O.............	.....	1.34	0.76	.....	0.67	.....	0.84	....
Sulphuric acid, SO_3:								
Combined.............	34.60	36.62	45.97	45.28	36.90	39.2	49.27	29.5–31.8
Free...................	0.40	.....	1.03	.....	.....	.....	.....	0.4– 0.1
Water.................	49.95	45.29	32.58	27.34	45.42	43.0	27.46	....

[1] Column 8 gives average composition of alum cake from clay.
[2] Soluble.

51. Reaction of Alum and Rosin Size.—When a solution of soap, such as rosin size, is mixed with a solution of aluminum sulphate, the alumina combines with the rosin part of the soap, and the soda portion of the soap is left to combine with the sulphuric acid from the alum solution, forming sodium sulphate. The combination of alumina and rosin is insoluble, and it immediately precipitates from the solution, coating anything with which it comes in contact. If, for instance, the mixing is done properly in the presence of pulp, all the individual fibers of the pulp are coated with this compound of alumina and rosin.

In the early days of chemistry, it was thought that the combination of alumina with rosin formed an aluminum-rosin soap; but later advances in chemistry have created the belief that, in addition to the formation of this soap, the precipitated material may contain free rosin and free alumina, the whole forming a complex jelly, the characteristics of which are modified to a very great extent by the proportions of the reacting materials originally present. The exact reaction is still a matter of controversy. In any case, the result of the reaction is a combination or mixture of alumina and rosin that is precipitated, and, on drying, this furnishes the water-repellant properties to the paper.

The amount of water resistance imparted to the paper depends not only on the manner of combination of these ingredients but also on their physical properties, which are influenced by the temperature, the state of dilution, and the rate of reaction of the various materials. These apparently simple reactions are really so complex, and are affected by so many physical conditions, as well as by various chemical impurities, that the more the subject is studied the more interesting and uncertain it becomes. The final result is also affected by the treatment in the machine room and the finishing room.

THE SIZING PROCESS

SAPONIFICATION OF ROSIN

52. Original Method of Saponifying.—The original method of saponifying rosin for use in sizing followed closely the general practice of soap manufacture. The rosin was boiled with a solution of soda ash, which contained somewhat more soda ash than was absolutely necessary to combine with all of the rosin.

When fully boiled, the whole was left to stand until the saponified rosin settled out to the bottom and a weak solution of alkali remained on top; this latter was then skimmed off, leaving the rosin soap ready for use.

This kind of size is still in use in many mills, and it is the most soluble form of size. It can be added in wax form, directly to a cold beater, and it is the safest kind of size to use, when there is no diluting equipment.

53. Modern Method of Saponifying.—In later times, it has become more common practice to use a rosin size that is not completely saponified; in other words, one that contains a certain amount of free rosin. The manufacture of this size is much simpler, and it is usually carried on as follows:

A steel tank, opened at the top, but preferably with a hood over it, is fitted with steam coils covering the bottom. Into this tank is put a solution of soda ash, which contains from 8% to 16% (by weight) of soda ash, figured on the basis of the amount of rosin to be cooked; the percentage may be varied, according to the character of the rosin and the finished size. The amount of water may vary from 50% to 100% of the amount of rosin. When this solution is heated by the steam coils (or by the live steam if perforated coils are used) to the boiling point, the rosin, broken up into small lumps, is shoveled in. It dissolves quite rapidly in the hot soda-ash solution, and gives up bubbles of carbon dioxide as the rosin combines with the soda. When all the rosin is in, cooking is continued for from 4 to 6 hours. The course of the reaction can be followed by watching the evolution of this gas, which continues to come up as long as there is uncombined soda ash present.

Another method of determining the completion of the cooking is to observe the way the cooked rosin flows from the end of a paddle that has been dipped in it. While being cooked, it runs off the paddle in long strings; but when the cooking is complete, it breaks off sharply.

Still another method for testing the size is to take a pint of size, mix thoroughly with a quart of hot water, thin with cold water until pail is almost full and examine for lumps, grains, and sticky particles of free rosin. The cooking should be continued until the test shows that the size may be diluted as above into a homogeneous milk, free from these indications of raw or poorly emulsified rosin.

54. To Make Soap Containing a Definite Per Cent of Free Rosin.—The amount of soda ash used in cooking the rosin determines the percentage of free rosin in the finished size. As an approximate guide to the manufacture of size containing various percentages of free rosin, the following table, which shows the results of the action of various percentages of soda ash on the rosin, may be used. The table is calculated for a rosin having an acid value that will neutralize 16% its weight of sodium carbonate, leaving 8.8% of rosin that will not saponify in aqueous solution.

SAPONIFICATION TABLE

Rosin (pounds)	Na_2CO_3 (pounds)	Rosin soap (pounds)	Free rosin (pounds)	Total size (pounds)
100	16	97.8	8.8	106.6
100	14	85.5	20.2	105.7
100	12	73.3	31.6	104.9
100	10	61.1	43.0	104.1
100	8	48.9	54.4	103.3

This table can be corrected for any rosin that has a different saponifying value; and since it is based on 100 pounds of rosin, the values in the several columns may be considered as per cents instead of pounds, if so desired. The first four rows give formulas for making the rosin sizes in general use. The first, in which 16% of soda ash is used, will make a so-called **neutral size,** which is easily dissolved; perhaps 20% to 25% of the mills in America still use this size and believe that it suits their conditions. A size cooked with 14% soda ash, having a total free rosin content of 20%, is a type of size quite commonly used; it is called **mill size.** The size cooked with 12% soda ash and holding about 30% of free rosin, is another type quite largely sold to mills having diluting systems. The size cooked with 10% of soda ash, containing 43% of free rosin, is a type used only in those mills having special systems for handling a high free-rosin size. The cooking may be done in the paper mill, or the mill may buy the prepared size.

55. Tanks for Cooking Rosin.—The size of the tank for cooking rosin should be at least double that necessary to contain the

finished size, because of the froth that rises up during cooking; hence, the tank will overflow, unless it has sufficient capacity. In the open size boiler, Fig. 9, provision is made for the froth to flow back into the tank A through the by-pass B; C is a steam coil.
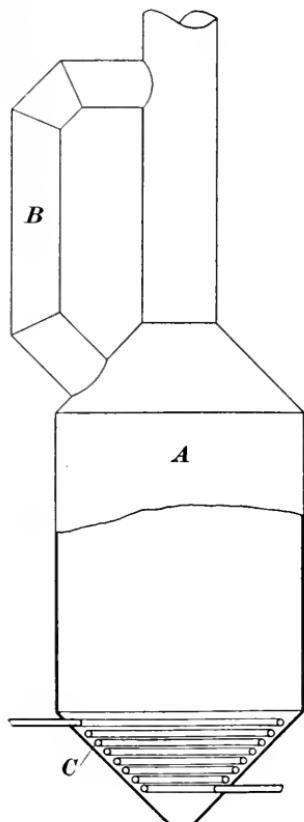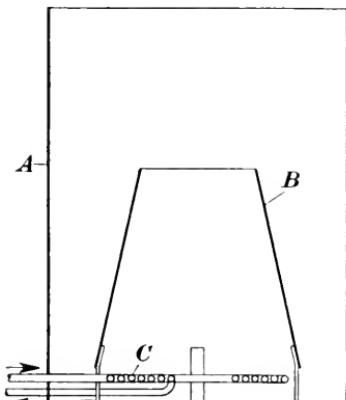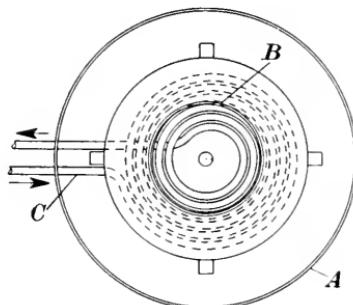
Fig. 9. Fig. 10.

In the modern American size cooker (patented) shown in Fig. 10, a truncated conical surface B is suspended over the coils C. The circulating action through the cone is so rapid that the size can be cooked violently and rapidly without boiling over.

56. There is another method of cooking which has been advocated in the past and is still sometimes used. The size is cooked in a closed tank, with indirect steam under pressure, either with or without an agitator. In Fig. 11, A is a pressure

size cooker, equipped with an agitator B, steam coil C, water inlet H, manhole M, and size outlet N. Instead of using coils, the lower half of a cooker is sometimes enclosed in a steam jacket.
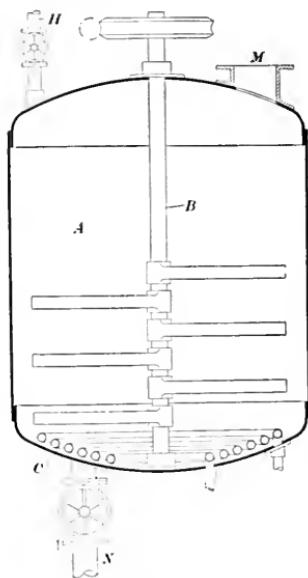
Fig. 11.

When cooking in this manner, the temperature can be brought to a point considerably higher than when cooking in an open tank; but the circulation, and the consequent uniformity of the finished size, is liable to be faulty, unless a special agitator is used. Under suitable conditions, the size can be cooked under pressure in less than 2 hours; in the open tank, from 3 to 6 hours are required. In former times, it was the practice to use an open tank, with direct steam, and this required boiling from 6 to 8 hours.

QUESTIONS

(1) State briefly the principles underlying the use of rosin sizing.

(2) (a) How is rosin obtained and graded? (b) What grades are used for sizing?

(3) What is meant by the term *saponified?*

(4) Give the chemical name, the molecular formula, and the characteristics of soda ash.

(5) (a) Give the common name for aluminum sulphate. (b) When is this substance acid? (c) when is it basic?

(6) Explain the process of cooking a batch of rosin size.

(7) How much soda ash should be used for 100 lb. of rosin to make a size having about 30% free rosin?

(8) By what signs can it be determined when the cooking of size is finished?

DILUTING SIZE

57. Reason for Diluting Size.—One of the critical operations in connection with the sizing process is that of diluting the thick size, or **wax**. In the case of neutral size, this operation is not so important, since the size is then soluble in water to such an extent

that it is generally added thick to the beaters, without previous dilution. The case is different, however, when size containing free rosin is being used. The object then is so to dilute the thick size as to make an emulsion of such a character that the free rosin is as reactive as possible. If this be not done, the separated rosin can produce lots of trouble on the paper machine. When the dilution is so carried out that the rosin in the emulsion formed is practically entirely invisible, it is then in the most reactive state. An emulsion in this condition contains the rosin in such fine particles that the whole forms what is known as a colloidal[1] solution. When alum is added to such a solution, all the rosin is precipitated as though a neutral size were used; except that the precipitate formed contains a larger proportion of rosin and less soda, which gives, generally, a more water-repellant coating to the fibers. If the free rosin is not invisible in the diluted solution, but appears very white and milky, the free rosin is in suspension, and it is not in a chemically reactive state. These rosin particles precipitate when the neutral soap in the solution is coagulated by alum, but the precipitate consists of small particles of rosin imbedded in the rosin-alumina complex. The sizing qualities of this mixture will vary with the coarseness and the amount of the rosin particles. The best sizing result can be obtained with the more chemically active emulsions, when other conditions are properly adjusted.

58. Free-Rosin vs. Neutral-Rosin Sizing.—It may here be remarked that there has raged, for some years past, a very sharp controversy as to the merits of free-rosin sizing as against neutral-rosin sizing; and many arguments, more or less correct, have been advanced in favor of one or the other. The advocates of the neutral size claim that the sizing is due to a resinate of alumina; those advocating free-rosin size claim that the sizing is due to the free rosin, and that the resinate of alumina has no effect. From the consideration of the physical chemistry of colloidal gels, it appears that the coating which furnishes the sizing qualities is a complex mixture, which consists of rosin, resinate of alumina, and alumina, and that no single one of these can be considered as being alone responsible for the sizing result. By both theory and practice, it is found that the characteristics of this gel, or coating, can be altered considerably by varying

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[1] A colloidal solution is jelly like, in that the particles are held in suspension in solution, and do not separate from the liquid in which they are suspended.

the conditions under which it is formed, and also by varying the amount and character of the free rosin in the size emulsion. It is only when these factors are adjusted to the mill conditions that the most efficient results can be obtained.

It cannot be said, however, that solutions of size containing free rosin are, on that account only, more efficient than neutral sizes; but it can be affirmed that when the free rosin is in a reactive state and properly utilized, the free rosin size can be made to give more efficient results than the neutral size. Bearing this in mind, therefore, the methods used in diluting sizes containing free rosin, which is the kind of size used in most mills at the present time, will now be discussed.

59. Methods of Diluting Size.—A size containing approximately 20% of free rosin can be diluted to make a fairly stable emulsion in moderately warm water; in many cases, a size of this constitution is added directly to the beater. It is unsafe to attempt to dilute a size containing more than 20% free rosin by adding it directly to the beater; for, if conditions are not just right, some of the particles may adhere to one another and form particles of rosin sufficiently large to show up as rosin spots in the finished paper.

The proper method of using higher free rosin size is to dilute it to an emulsion containing approximately 2% of rosin, and then add this emulsion to the beater. This dilution is generally accomplished by adding thick size to hot water, with violent agitation. This may be effected by blowing the size into a tank of hot water in a fine stream jet, or by adding it in small quantities and stirring violently at the same time. When first made, such an emulsion is of fairly good character, provided the agitation has been sufficiently violent and the size has not been added too quickly. Unfortunately, however, an emulsion of this character, when hot, tends to destroy itself as an emulsion, owing to the fact that the rosin particles agglomerate, and the emulsion gradually becomes more and more milky. If kept hot for a sufficient length of time, the particles will become so large as to settle from the emulsion, leaving the remainder of less value. By chilling the partially diluted size with cold water, this difficulty might be avoided; but it is hard to do this without causing further decomposition.

By using a system of graduated dilution, a better emulsion can be obtained. This is accomplished by first diluting the size

to a consistency of about 25% solids, and then adding, at a boiling temperature, a certain number of parts of water, the amount of which will vary in accordance with the free rosin content of the size. After the size has been diluted to this stage, and it will rapidly disperse in cold water.

Suggestions have been made at various times that other substances might be added to the hot water, or to the size, which would act in such a manner as to protect the size particles from this tendency to agglomerate into larger ones. Substances having this property are known as protective colloids, and they include many materials of a gelatinous character. The addition of these substances has a very definite effect; but the advantage to be derived depends upon the material used and upon the conditions under which the sizing is done.

The disadvantage from the use of these materials is the fact that a tendency to froth is often produced, and more coloring matter may be introduced, which will effect the brightness of the paper

60. Diluting System.—There are two well-standardized systems for diluting a thick size. In one of these, the process consists of mixing the thick hot size with a small quantity of hot water, at a definite temperature, within an injector, and violently agitating the size and water, at the moment they mix, by means of steam pressure, which is applied to the hot water from a jet of steam. An instantaneous solution is accomplished in this way; and its physical character is preserved by using the same pressure of steam to blow the mixture into a large amount of cold water, which immediately stabilizes the emulsion. An emulsion that may contain as much as 50% free rosin can be made into what is practically a purely colloidal solution having the maximum sensitiveness to reagents, such as alum. Fig. 12 shows the arrangement of this system, the lettered parts being as follows:

A and *B* are barrels of rosin; *C* is a cooking tank, heated by steam pipe *D*; *E* is a measuring tank; *F* is the heating coil; *V* is the emulsion tank; *H* is a device for mixing heated rosin soap from *E* with water from *V* (through pipe *L*) and steam from *T*, which injects the mixture into *V*; *W* is a connection for supplying water during emulsification; and *R* is a storage tank.

61. The other diluting system, illustrated in Fig. 13, consists, essentially, of a steam injector, so designed that the hot size

flows from heated measuring tank A into the injector B; from B,
it is forced by means of a steam jet from steam pipe C into hot
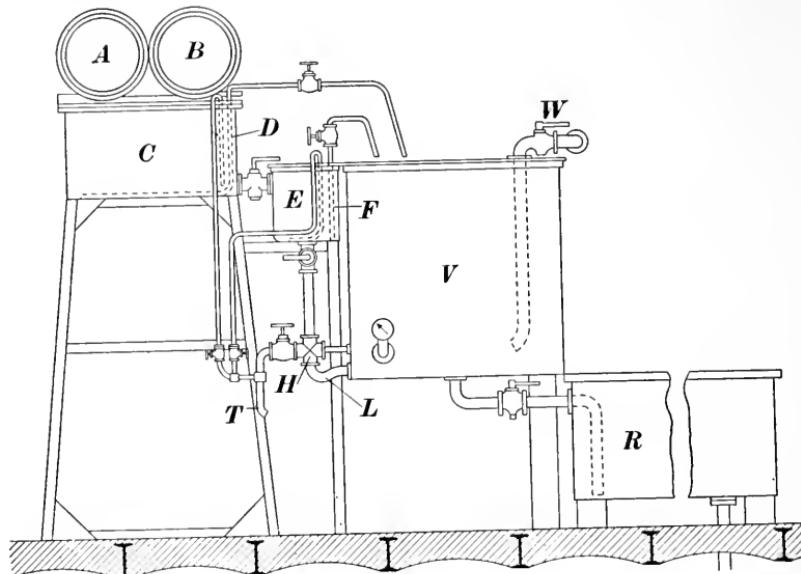
Fig. 12.

water in D, and some cold water is finally added through E.
F is a perforated steam coil, which heats the contents of D and
assist in mixing.   Details of the injector are shown at (b).
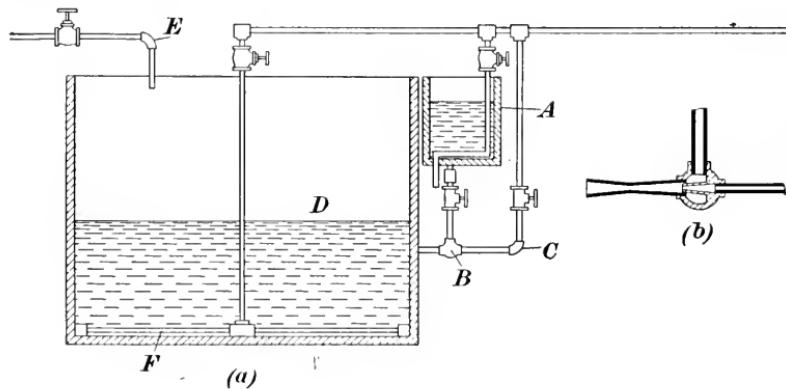
Fig. 13.

62. A later development of this method consists of a pressure
tank holding hot size, from which it is forced under pressure
directly into a tank containing hot water.   This process has

some advantages over the steam injector; but here, also, there is not much control over the operation. It is being operated generally with a size carrying from 25% to 30% free rosin.

Two other methods are still used occasionally: One is to drop the hot size directly from the cooker into a tank containing twice as much hot water, which is stirred by an agitator; when completely mixed, cold water is run in and mixed until the correct volume is obtained. The other is to feed the hot size along with hot water into a fan pump, from which it is discharged into a diluting tank. Either of these methods may be used with a size carrying 25% or less of free rosin.

63. Handling Diluted Size.—As it is seldom possible to use the size immediately after it is diluted, it becomes necessary to store it until the stock is ready to receive it. Most mills prefer to keep a fairly large supply of diluted size emulsion on hand; this is generally kept in large tanks, the capacity of which depends on the amount being used daily in the plant. About one day's supply is the amount usually kept for this purpose, though the amount thus stored may be varied, being greater or less, to suit the working conditions of the mill. A well-made emulsion will keep quite well at ordinary temperatures for a considerable time.

64. Effect of Hard Water.—The water used in diluting the size should be as soft and pure as possible. As a general rule, however, it is impossible to obtain absolutely pure water; and a certain degree of deterioration in the emulsion must be expected, on account of the salts dissolved in the water. These salts act in a manner somewhat similar to alum, and they precipitate a portion of the size. The salts of lime and magnesia form insoluble soaps (resinates), which produce a thick scum on the emulsion tank. This is merely a verification of what happens when the size is discharged into a beater full of hard water; it explains why it is necessary for a mill using hard water to increase the amount of alum in order to get the lime out of the way.

Salts such as sodium chloride, sodium sulphate, and other salts of the monovalent elements, are almost equally detrimental; if they are sufficiently concentrated, they will tend to break up the emulsion and slowly coagulate it. They displace the rosin

soap in the solution, because they are themselves more water soluble.

65. Furnishing the Beater.—In mills using diluted size as above described, it is the general practice to pump the diluted size from the storage tanks to the beaters. For measuring the size at the beater, a tank should be placed either over the beater or somewhere near and handy to it; and it should be equipped with a gauge that is graduated to show the amount of rosin per inch of depth of the measuring tank. The graduation of this gauge may be simply in inches, or in pounds of rosin, or in terms of some unit to which the mill has become accustomed, such as a pail or a dipper. Some prepared rosins are added directly to the beater, and directions call, usually, for so many dippers.

All these methods are in use; but it would seem that the most logical procedure would be so to graduate the measuring tank that the number of pounds of rosin for a given volume could be stated definitely.   It is frequently possible to use one measuring tank for a pair of beaters, if they are close together. These tanks should have a wash-out connection for cleaning.

66. Adding Alum.—While alum may be, and frequently is, added to the beater in ground form, it is considered better practice to dissolve the alum first and add it in the form of a concentrated solution. Alum solutions are very corrosive to iron; they should not be handled in anything but wooden pails, and should be stored or contained only in wooden or concrete tanks having bronze fittings. Concrete tanks for holding alum must be specially prepared and treated, to resist the corrosive action of this acid salt.

The common form of an alum-diluting system consists of a wooden tank, with an agitator; this is worked on the batch (intermittent) system, and is used to dissolve ground alum.   The cheapest method is to buy the alum in large cakes, and to keep a large tank (without agitator) filled with these cakes.   The tank is also kept filled with water; and a fairly strong solution can be taken from the bottom, the density of which will vary with the temperature of the water and the length of time of contact.   Some mills use two tanks equipped alike, one being used as a storage tank while alum is being dissolved in the other. The solution is kept uniform.

PROPORTIONS OF SIZE AND ALUM AND ORDER OF FURNISH

67. Complexity of Reactions.—The problem of sizing is extremely complex. Different reactions take place between the rosin and the aluminum sulphate, which depend on the amount by which the aluminum sulphate exceeds the amount actually needed to react with the rosin soap. When no other factors intervene, a definite ratio may be determined for a size having a fixed percentage of soap and for certain mixing conditions. The whole reaction is made uncertain by the presence of other reactive salts, which are either in the water or in the stock; and these salts are of such a complex character that no definite formulas can be given that will apply to every case.

As a general rule, the size goes into the beater before the alum; but there are cases where there are so many injurious reactions lying in wait for the size that it suffers less injury by going in last. Where hard water is used, it may be advisable first to add enough alum to take care of the hardness.

68. Amount of Alum Required.—A general idea of how the size and alum react on each other can be obtained by assuming that no impurities are in the paper stock or in the water that contains it. Also, that the size and alum have both been properly diluted, and that soft water is used in furnishing the beater, which is not heated. Under these conditions, it may be stated that a size containing from 35% to 45% of free rosin would require about 15 pounds of alum for every 10 pounds of rosin.

Under similar conditions, a size having from 20% to 25% of free rosin should require about 20 pounds of alum for every 10 pounds of rosin used; and a size that is fully saponified and alkaline might require 30 pounds of alum for every 10 pounds of rosin used, to produce proper characteristics in the rosin precipitate and in the fibers.

These ratios have no basis in theory, because, theoretically, it ought not to require over 4 pounds of alum for every 10 pounds of size; but, in actual practice, the proper combinations are not effected unless the alum is used in large excess; and this excess must be greater the more there is of rosin in the form of soap. The figures given may be used as a guide only. The right proportions of alum and size must be determined empirically for each mill; and the proportions will vary with the character of the stock and water and the methods of reclaiming back water.

Difficulty may be experienced in sizing if steam is blown into the beater, as is sometimes done to "free" the stock, or if the stock becomes heated through beating action.
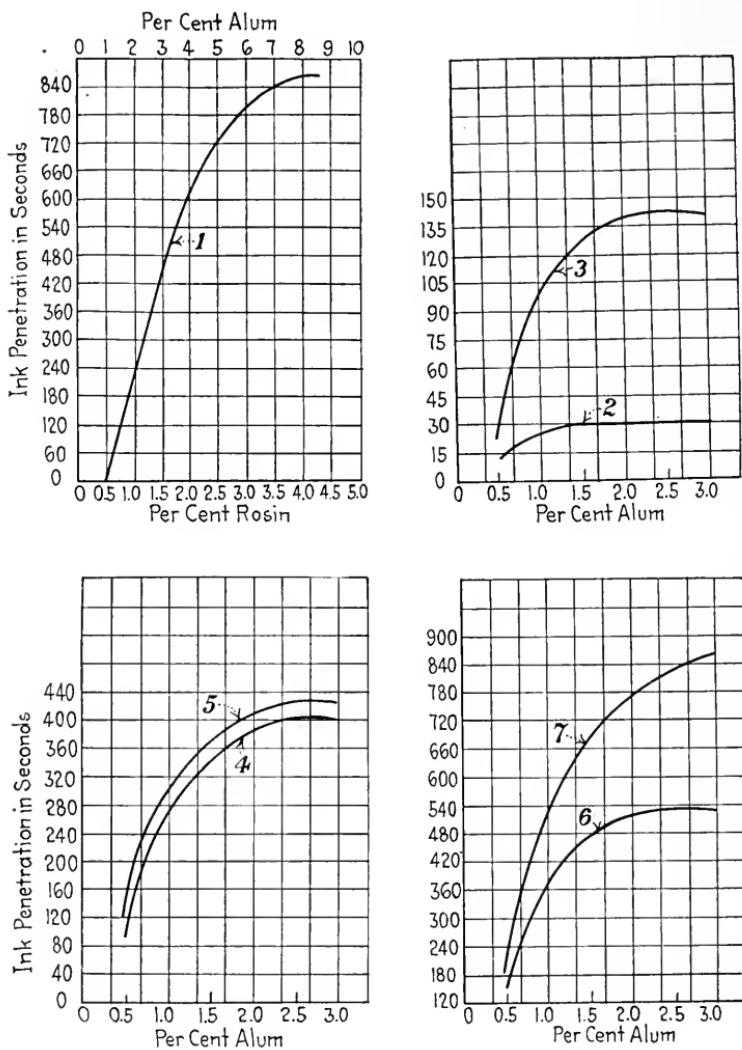
Fig. 14.

69. Variation in Water Resistance.—The amount of water resistance that can be obtained in paper by the use of rosin size, depends upon the kind of size, the method of using it, the amount

and kind of alum used, the character of the pulp, the amount of and temperature of beating, the formation of the sheet on the wire, the methods of extracting the water, and the manner of drying and calendering.

It was stated in the Section on *Properties of Pulpwood*, Vol. III, that resins change on exposure to sun and air. This accounts for the fact that paper that has been exposed to sunlight becomes gradually less water resistant.

What can be accomplished under good water and mill conditions, using a 40% free rosin size, properly diluted, is shown in curve No. 1, Fig. 14, which was presented by Paul Bray to the Technical Association of the Pulp and Paper Industry at New York, Feb. 6, 1918. The curve shows that, under good conditions, the maximum sizing effect is obtained with 4% of rosin. He also determined the sizing results when using a constant amount of rosin and varying the alum. Beginning with 0.5% of rosin on the weight of paper stock, he obtained curve No. 2 and other curves, Nos. 3 to 7, for each additional $\frac{1}{2}$% until 3% of rosin was reached. Thus, for curve 2, the rosin was constant at 1%; for curve 3, the rosin was constant at 1.5%; etc. The ordinates (vertical measurements) in each case give the number of seconds require for a standard ink, at constant temperature, to penetrate paper floated on it.

In another mill using the same kind of size and alum, but having different water and stock conditions, the curves showing the sizing results would be different under the several alum ratios. If a size were used containing no free rosin whatever, or if the size were decomposed on diluting, a still different curve would be shown, and the maximum result would be lower. Sutermeister points out (Chemistry of Pulp and Paper Making) that loading very materially reduces the sizing effect. Some fillers affect it more than others.

70. Other Substances Added to Produce Special Effects.— There is no real substitute for rosin in sizing paper, but there are a number of materials that can be used with it to produce special effects. One of these is *sodium silicate*, "water glass," which, when precipitated with aluminum sulphate, gives a mixture of silica and alumina, which has a hardening effect on the paper.

71. Sodium Silicate Na_2SiO_3.—Sodium silicate is one of the most attractive and, at the same time, one of the most difficult

materials to use as a sizing ingredient. The properties of the silicate are so different from those of rosin that it cannot be considered in any way as a rosin substitute; but it can be used to alter the characteristics of the paper and to modify the effect of the rosin sizing. Many users of sodium silicate have had unsatisfactory results, either owing to the method of using it or because the properties obtained from it were not suited to the kind of paper treated.

New methods of using sodium silicate that will extend its sphere of usefulness may yet be developed. It gives hardness and stiffness to the paper; and it is largely used by those paper manufacturers who are not able to get sufficient snap in their papers by other means. On some classes of paper, it will increase the Mullen test, but it will also reduce the folding qualities.

72. Synthetic Resins.—During the World War, coumarone resins were used in Germany. They could not be saponified in the usual way, but were emulsified by means of rosin soap or glue. The production of a good synthetic resin has been the subject of much chemical research.

73. Casein.—Casein is sometimes used in a beater for a special purpose, such as keeping down fuzz, or for increasing elasticity. It is dissolved by treating with an alkali, and it is precipitated by alum or other acid in a manner similar to rosin. Casein is relatively expensive, and it is likely to give the paper an unpleasant odor, unless used with great care.

74. Starch.—Starch is used in sizing paper, both in engine and in tub sizing. As an engine size, it may be used alone or with sodium silicate. For tub sizing, a modified, or thin-boiling, starch is generally used.

Starch does not make paper water resistant; but it imparts a certain slickness to the paper on calendering, increases the strength, imparts snap and rattle, and reduces fuzz on certain kinds of stock.

When used in the beater, the starch may first be swollen and gelatinized by boiling; or the raw starch may be added directly to the beater, which should be done early enough in the process to get thorough mixing. The gelatinization of the raw starch, which makes it effective, is partly accomplished by the heat of the paper dryers.

INDIRECT EFFECTS FROM SIZING

75. Color.—It is well recognized that rosin will give a yellowish tint to paper, and this must be offset as much as possible by the aid of blue coloring matter. The color effect of rosin becomes noticeable when over 1% of rosin is used. Inasmuch as the higher grades of rosin are not the best for sizing, it is important, in order to obtain the whitest color in the paper, that the sizing should be well done, using only the smallest quantity of rosin possible.

76. Strength.—The binding power of rosin size in the paper fibers is greater than the natural adhesion of groundwood or waste-paper fibers to one another, but is less than that between sulphite, sulphate, or rag fibers. In the manufacture of strong paper, the sizing problem is quite important, because low sizing efficiency means an excess of rosin to get the sizing standard required; and this, in turn, may reduce the strength of the paper materially.

77. Finish and Retention.—The finish of the paper often depends on the amount of filling material, in the form of fine fibers and mineral fillers, that is retained in the sheet as the water is drawn from it in during its formation on the wire. Since it is harder to polish a rough surface than to polish a smooth one, the fine material used to fill the voids between the larger fibers should be held evenly on both surfaces of the paper. When the sizing is of poor quality, more of the filling material is lost through the wire, and the paper is not only lighter in weight than it ought to be, but the wire side of the paper is rough, and it will generally show feathering action when written on with ink.

78. Hardness.—The hardness of the paper surface depends partly upon the paper stock and the treatment in the beater; but when these factors are constant, the degree of hardness or softness of the paper can be varied by the kind and quality of sizing materials used. A good quality of high free-rosin size will produce a snap and hardness in the paper that cannot be obtained by the use of a neutral or low free-rosin size.

The use of glue in the size will also increase the hardness, but it is a more costly agent for this purpose. Glue is generally used for tub, or top, sizing, as explained in the Section on *Tub Sizing and Finishing Operations*. When the paper stock is to be tub

sized or coated it must not be so well sized with rosin that the glue will not penetrate the paper, or the coating fail to adhere.

79. Rosin Spots.—If suspended free rosin is in a sufficiently soft or molten condition when added to the paper stock, it will adhere either to the paper fibers or to the wires or presses, and it will gather other particles of rosin until masses of rosin are formed. These masses may cause translucent spots in the paper, or they may retard the operation of the machine. These troubles always occur when improper methods are used in dissolving or diluting a high free-rosin size.

There are other rosin spots that may come from the natural resins and waxes of the wood; they may arise from an unbleached sulphite fiber, or from mechanical pulp made from a green, semi-resinous wood. The pulp pitch is a softer material than colophony rosin, and when it causes machine troubles, it can be readily recognized.

80. Froth Spots.—When the paper stock has a tendency to froth, as a result of the kind of size used or of impurities in the water or pulp, and when, in treating the stock, there is a considerable amount of agitation, there is then likely to be an accumulation of froth on the screens and at the slices on the machine. This froth carries in the bubble film a certain amount of pulp, which is liberated when the foam is broken down by showers. The pulp will be sticky and resinous, and if it gets on the machine wire, it will leave a dirty splotch on the top surface of the paper.

Froth can be prevented from foaming by lack of agitation, or it can be reduced by altering the surface tension conditions in the rosin size; a little kerosene is sometimes added to the stock for this purpose, but it is injurious to the sizing. A light froth that does not carry many pulp fibers will cause very little trouble.

QUESTIONS

(1) Describe one method of diluting the size for use in the beater.

(2) How and when should size and alum be added to the beater?

(3) What determines the proportions of size and alum required?

(4) What is the effect on sizing of (a) loading? (b) temperature of the beater?

(5) What are some of the troubles that may arise from sizing? Suggest a remedy for each.

SIZING DIFFERENT KINDS OF PAPER

81. Newsprint.—This grade of paper uses the least amount of size, it being the general practice at the present time to leave out the size altogether. Newsprint is sometimes sized, however, especially in the case of paper produced for export, because it assists in giving the paper the best finish and printing qualities for certain kinds of work.

One way to improve the finish and printing qualities for the best grades of newsprint is to make use of the beneficial properties of clay; but the use of clay is considered detrimental to speed on fast-running American paper machines. In order to get a reasonable retention of clay, it is necessary to use size. The highest grade of foreign newsprint may contain from 10% to 20% of clay; under American conditions, 1% to 5% would be more usual, and this would apply to special grades, as half-tone, rather than to standard newsprint.

The modern tendency is to make newsprint at a great speed, and to mix the stock in great tanks or chests, without beating or sizing. If any sizing effect is required to be obtained under these manufacturing conditions, very dilute solutions should be used, and they should be carefully prepared. Hanging, or wall paper, is generally classed with newsprint. It is not a difficult paper to size.

82. Book Papers.—The engine sizing of book papers is dependent to a considerable extent upon the amount and kind of loading used. Proper sizing standards are very important; but the chief characteristic required in this class of paper is printing quality, which is indirectly affected by the amount of rosin sizing. A large amount of book paper has no sizing, but the average furnish would be about 1% of rosin.

It is economical to use rosin in all well-loaded papers, because of the increased retention of filler that can be obtained. This feature is probably more important than the sizing effect, since printing ink contains oil and does not require water resistance in the paper.

83. Coated Papers.—Coated papers or papers to be pasted require that the degree of water resistance be not so great as to prevent some penetration by the water in the coating mixture; this is necessary to cause proper adhesion of the coating to the paper.

84. Bond and Writing Papers.—These papers are made from either sulphite or cotton fibers, or are from mixtures of both. They contain very little loading, and the results from engine sizing depend largely upon the chemical and physical properties of both the cellulose and the rosin. The problem of sizing these papers is more complicated than with any other grades. The stock is occasionally injured in bleaching. The amount of hydration is important, and this class of paper seems more sensitive to machine conditions. The problem of sizing is here sometimes complicated by considerations of coloring.

85. Wrapping Papers.—There are three main classes of wrapping paper: kraft, or sulphate-fiber, papers; dry-finish sulphite-fiber papers; water-finish sulphite-fiber papers. In addition, there are real manila papers made from rope, which are very strong, and bogus manila papers made chiefly from ground wood, which are very weak.

The kraft wrapping papers and the groundwood papers are easy to size, and they respond uniformly to well-prepared free rosin solutions. Kraft paper is sized with from 0.5% to 2% rosin. The lowest amount of rosin is used in twisting paper, and the highest amount is used in tape papers.

86. The dry-finish sulphite papers are usually more difficult to size, owing to variations in the character of the pulp, which does not always respond to sizing reactions.

In water-finish sulphite wrapping papers, the sizing is practically destroyed on the calenders. It must be well sized, however, when it leaves the dryers, or it will break on the calenders. The water penetration test of this class of paper will be 5 to 15 minutes, as it comes off the dryers, and 20 to 100 seconds, as it leaves the calender rolls.

An excess of rosin is injurious to the strength of the fiber. The best product for these papers is made with hard sulphite and hard sizing.

87. Wallboard.—Wallboard is exposed to conditions where it is desirable to have the least amount of expansion and contraction. The rate at which moisture may be absorbed by wallboard can be retarded by rosin sizing, and the total amount of water absorbed can be restricted by the same means.

Although surface coatings are often applied to pasted board to prevent expansion and contraction, it has also been proved to be

desirable to have the solid board sized hard enough to prevent the absorption of the pasting fluid.

88. Testboard.—This product is used for making containers of various kinds; it is a kraft-lined board, of which the liner is hard sized. Special difficulty is found in sizing this board because it is generally given a water finish, which is always injurious to rosin sizing.

The paper maker must maintain a delicate balance between the amount of finish and the amount of rosin required, since the water resistance will vary inversely with the amount of pressure applied in the water finish.

89. Rope and Grease-Proof Papers.—Rope stock is very hard material to size, because, probably, of the method of boiling the stock, the excessive beating, and the calendering conditions.

Grease-proof papers are always poorly sized, owing to the calendering methods used for producing the translucency.

LOADING AND ENGINE SIZING

EXAMINATION QUESTIONS

(1) (*a*) Name five substances commonly used as loading for paper. (*b*) State which are natural products and which are manufactured products.

(2) What are the usual impurities in clay, and why are they objectionable?

(3) (*a*) Explain the purpose of adding a filler to paper. (*b*) How much filler is generally used?

(4) (*a*) What is meant by retention? (*b*) What factors increase retention?

(5) How may the fineness of a filler be determined?

(6) How is the amount of iron in a filler estimated?

(7) Mention two important differences between engine sizing and tub sizing of paper.

(8) (*a*) What is rosin, chemically? (*b*) Why is carbon dioxide given off when rosin is saponified with soda ash?

(9) Why is the amount of iron in aluminum sulphate important?

(10) What happens when rosin size is mixed with a solution of aluminum sulphate in the presence of paper pulp?

(11) What effect does the amount of soda ash used to make size have on the amount of alum required in the beater?

(12) What effect does hard water have on rosin size?

(13) Why is paper sized, and how is the effectiveness of sizing determined?

(14) Name two substances that may be added to the beater for special effects, and tell what they do to the paper.

(15) What effect has sizing on color, strength, finish, and hardness of paper?

(16) State the sizing requirements of five kinds of paper.

SECTION 5

COLORING

INTRODUCTION

AUTHORSHIP: This Section was prepared by the Dyestuff Committee of the Technical Association of the Pulp and Paper Industry—Charles G. Bright, Ross Campbell, C. C. Heritage, Kenneth T. King, Clarke Marion, and Carl Schneider, in collaboration with Dr. Otto Kress.

1. Scope and Purpose of this Section.—The pleasing appearance required of the finished paper depends very largely upon the proper manipulation of the coloring processes. The importance of this branch of paper manufacture is realized when it is considered that fully 98 per cent of the tonnage of paper produced is colored in some form, ranging from the tinting of all types of white paper to the production of heavy shades in the standard grades and specialties. Past experience has proved that efficient progress in methods of application has been aided by the cooperation of paper and dyestuffs manufacturers, and the necessity for such cooperation will be made apparent in the following pages. It is the purpose of this Section to place before the reader such information on dyestuffs and their application to paper as is essential to the production of the proper shades and colors. At the same time, a foundation will be laid for the subsequent work that will ultimately be done in connection with the general advancement in manufacturing operations.

While a knowledge of chemistry and physics is of great advantage in studying the application of dyestuffs to paper, it is not as important as a thorough practical knowledge of the working qualities of the individual dyestuffs and of the stocks on which they are used; consequently, no further knowledge of chemistry will be required than is contained in the Section on *Elements of Chemistry*, Vol. II, which the reader is assumed to possess.

Superintendents, beater engineers, and students of paper manufacture should be familiar with the properties of the various

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groups of dyestuffs, the variety of dyestuffs in each group, and the action of individual dyestuffs during the process of coloring. A practical working knowledge of the equipment used, and of the different methods of application as applied to various types of equipment, should be acquired. The foregoing, together with a short history of the dyestuff industry, will form a nucleus for a thorough understanding of this subject, which should be supplemented by practical experience in the mill.

2. History of Coloring of Paper.—The coloring of different substances has engaged the attention of man from the earliest ages. Records of the coloring of fabrics go back as far as the year 2000 B. C. With the beginning of manufacture of hand-made papers, it is recorded that vegetable stains and minerals were used for coloring purposes.

Until the latter part of the nineteenth century, paper was colored with pigments, vegetable colors, and lakes (insoluble compounds made from vegetable colors); but, due to the comparatively few pigment and vegetable colors produced, the variety, quality, and uniformity of shades thus obtained were in no way comparable to those made possible by the discovery of the aniline dyestuffs.

3. Mauve, the first aniline dyestuff, was discovered by Sir William Henry Perkin, in 1856, in an attempt to manufacture synthetic quinine by the oxidation of aniline oil. Although this discovery was quite accidental, it formed the basis for the development of many other aniline dyestuffs, and for the subsequent adoption of them by the textile industries. While the manufacture of aniline dyestuffs thus dates back to 1856, their use in the paper industry was negligible until about the year 1890, when their cost of manufacture had been reduced to a point that permitted their use in the manufacture of paper. Between 1890 and 1914, there was a wonderful development in the European dyestuff industry, not only in the variety of products applicable to paper but also in the reduction to very low levels of the cost to the consumer.

4. While the first aniline dyestuff was discovered by an Englishman, keen interest was exhibited by both France and Germany during the early stages of the development of the dyestuff industry. As time went on, Germany began to realize the

importance of such an industry, and she gradually drew ahead
of her English and French rivals, due more to the active support
of the German Government, which subsidized the young industry,
than to any superiority of the German chemist over his con-
temporaries in other countries. While the business was still in
its infancy, the German Government recognized clearly the
advantage of building up an industry that would yield good
profits in peace times, and which could readily be converted
into an organization for the manufacture of munitions of war.
That the Germans were correct in their successful efforts to
secure a strangle hold on the dyestuff and organic chemicals
industries was amply proved by the events subsequent to 1914.
Prior to 1879, the Germans had absolute control of the dyestuff
industry in the United States. Although from that time to 1914,
there were a few companies in this country manufacturing
dyestuffs, they were made principally from German intermedi-
ates. Through the indulgence of the Germans, the American
companies were allowed to continue operations, but only to an
extent by which the Germans might benefit through considera-
tions and regulations of the tariff. Several efforts were made by
domestic companies to become established on this continent, but
they could not compete, on a scale of appreciable magnitude,
with the subsidized companies of Central Europe.

The recent World War, with its resulting shortage of dyestuffs,
proved the necessity for the establishment of a domestic dye
industry. Those concerns which were making small quantities
of a few dyestuffs rapidly expanded, in the effort to meet the
abnormal demands caused by the stoppage of the European
supply. Many new companies were formed, with the result
that, today, the American dyestuff manufacturers are able to
meet the demands of the paper industry.

5. Source of Aniline Dyestuffs.—Aniline dyestuffs are deriva-
tives of certain products obtained from the distillation of coal
tar. By subjecting these crude products or **crudes,** as they are
termed in the trade, to certain chemical processes, **intermediates**
are obtained. On further treatment, the intermediates may be
converted into dyestuffs, explosives, poisonous gases, and drugs
or pharmaceutical preparations. A plant which, in normal times,
is devoted to the production of dyestuffs can thus be readily
converted into one for the manufacture of various chemicals
used in warfare; and, at the same time, it can produce the

dyestuffs required by the manufacturers.   More important even than plant equipment is the training of a large staff of chemists and chemical engineers, who are fitted by education and experience to carry on any research work connected with the exigencies of warfare that they may face.   The bond is close between the dyestuff industry and the organic chemicals industry as a whole. There is no branch of chemical industry where a thorough appreciation of the principles of chemistry is more necessary, or where a greater variation in plant methods and equipment must be employed.

Pigments and many natural organic dyes, which had not been on market for several years, owing to the scarcity of aniline dyestuffs during the years 1914–1918, inclusive, are now available in various forms.   At the present time, the paper industry has at its disposal a complete line of the aniline dyestuffs necessary for its use, together with a larger volume of pigments and natural organic dyes than were available before the war.

DYES AND THEIR PROPERTIES

CLASSIFICATION OF COLORING MATERIALS

6. Definitions.—**Dyeing** may be defined as the art of coloring (or changing the color of) any material by bringing it into contact with another material of different color in such a manner that the resulting color will be more or less permanent, not being easily altered when the dyed material is subjected to such influences as heat or light, washing, etc.   The material used to change the color of some other material is called a **dye** or **dyestuff**.   It is not sufficient merely to bring into intimate contact two materials of different color.   For instance, very finely powdered charcoal may be thoroughly mixed with water to form a black solution; into this, a white cotton cloth may be dipped and soaked, thereby turning the cloth black.   The cloth will not be dyed, however, because by a thorough washing and rubbing, it can be made to resume its original color.   To be truly dyed, the coloring matter (dye, or dyestuff) must adhere or cohere to the fiber, and it must be more or less unaffected by such physical and chemical changes as the material may receive.

If a material has been so colored that its color is changed very little, if at all, by the action of light, heat, washing, etc., the dye used is said to be **fast,** and the resulting color is said to be a **fast color;** if, however, the color changes, usually becoming lighter, or changing shade, it is said to **fade.**

Some dyes will not produce the desired color by direct action on the fiber—they will not *stick*, as it were. In such cases, another agent, called a **mordant,** is used. The mordant adheres to the fiber, the dye adheres to or combines with the mordant, and the dye thus becomes **mordanted,** or **fixed.** A mordant is defined as "a substance which, when applied to the fiber in conjunction with a dyestuff, combines with the latter to produce a useful color."

7. Three General Groups of Dyes.—Coloring matters are divided into three general groups; namely, aniline dyestuffs, pigments, and natural organic dyes. The first two groups will be discussed in detail; but in regard to the third group, all that is necessary to say here is that the natural organic dyes[1] include logwood, the red woods (camwood, barwood, sanderswood, brazilwood, peachwood), madder, cochineal, the yellow woods (weld, old fustic, quercitron bark, flavine, young fustic), and Persian berries. All these natural organic dyes require the use of mordants, or other chemical treatment. According to Reginald Brown, F. C. S., indigo, turmeric, orchil, and catechu are used without mordants.

8. Reasons for Using Aniline Dyes.—Of the three groups of dyes, the first group is used more largely than either of the others in the manufacture of paper. Though certain pigments are used in considerable amounts, aniline dyes predominate for the following reasons: (*a*) They embrace a wider range of shades than pigments or natural organic dyes; also, on account of their great variety, they afford more of an opportunity for choice as regards cost, tinctorial power, brilliancy, and resistance to various influences, such as light, acids, or alkalis. (*b*) Aniline dyestuffs do not decrease the strength of finished paper, as is the case with pigments. (*c*) They are easier to handle in the mill than pigments or natural organic dyes, both with respect to manipulation and to uniformity of results. (*d*) With few exceptions, aniline dyes are the cheapest.

[1] None of these now are used much, if at all, in the paper industry.

ANILINE DYES

9. Classification of Aniline Dyes.—From the standpoint of practical application, aniline (or coal-tar) dyestuffs are not classified according to their chemical constitution, but are grouped in accordance with their general properties. There are five such groups; namely basic, acid, direct (or substantive) dyestuffs, sulphur colors, and pigments from vat dyes of the anthracene series. Each group has distinctive chemical and physical properties relative to their action on the fiber and in their method of application. In order to identify a color by name, it is necessary to know three things: first, the trade name; second, the shade or the distinguishing letter; third, the manufacturer.

10. Trade Names and Distinguishing Letters.—The **trade name** usually bears a reference to the class, properties, chemical constitution, or color of the dye, such as acid blue, fast red, methylene blue, etc.; but, in many cases, it is simply an arbitrary name, such as Auramine or Rhodamine, given to it by the discoverer or by the first manufacturer.

No fixed rule applies to the **distinguishing letters** following the name of the dyestuff. However, R usually applies to a red shade, 2R to a still redder shade, G or Y to a yellow shade, B to a blue shade, and X or Conc. to the more concentrated brands. Some form of the name of the manufacturer often prefixes the trade name, in certain cases, this designates their class. For example, the names Du Pont, pontacyl, pontamine, and ponsol, of E. I. DuPont de Nemours & Co., signify basic, acid, direct, and vat dyes, respectively.

11. Basic Dyestuffs.—**Basic dyestuffs** are so called because they have a similarity in their chemical behavior to such inorganic bases as caustic soda ($NaOH$) or ammonium hydrate NH_4OH. They appear on the market in the form of a salt, such as the chloride, acetate, oxalate, or nitrate, in which the molecular formula corresponds to (dye base)-oxalate, (dye base)-chloride, etc. Basic dyestuffs are marketed in this form because the color base itself is insoluble in water and must be treated with an acid, to form soluble salts; just as aniline, which is but slightly soluble, becomes the very soluble chloride on treatment with hydrochloric acid.

Basic dyes are characterized by their extreme brightness and great tinctorial power; but, as a class, they possess poor fastness

to light. All basic dyestuffs can be mixed and dissolved with others of the same class; but they should not be mixed or dissolved with acid or direct colors, as they would be thereby precipitated as color lakes.[1] Not only would the color then be wasted, but the precipitated lake would be apt to produce color spots on the finished paper.

Basic dyestuffs are very sensitive to hard water, bicarbonates of lime or magnesia, or any free alkali. When an alkali of this kind is present, it neutralizes the acid, setting free the insoluble dye base, which will appear in the finished paper as a color spot; 50 parts per million of bicarbonates may give trouble. It is for this reason that the recommendation is here made that acetic acid be added before the dyestuff, if trouble from this source is experienced.

When dissolving basic dyestuffs, they should never be boiled; they are best dissolved at a temperature that does not exceed 200°F. Upon boiling, there is a tendency to hydrolyze the dyestuff salt, thereby forming an insoluble base, which greatly reduces the coloring power of the dyestuff. Certain basic dyestuffs, such as auramine, basic brown, Victoria blue, should never be dissolved at a temperature exceeding 160°F.

12. Acid Dyestuffs.—Acid dyestuffs also appear on the market in the form of a salt; they are so named because, in the salt, the dye radical takes the place of the acid constituents and gives a molecular formula such as sodium-(dye acid) or potassium-(dye acid).

As a class, acid dyestuffs have a lower coloring power than basic dyestuffs, but they are much faster to light; and on mixed furnishes, give more even dyeings than basic or direct dyestuffs. Acid dyestuffs have no direct affinity for cellulose fibers; they are merely mordanted, or fixed, to the fiber by the presence of size and alum.

13. Direct, or Substantive, Dyestuffs.—The **direct,** or **substantive dyestuffs** are also salts of color acids, being differentiated from the acid dyestuffs by the fact that they do not require alum or, when used in the textile industry, an acid, to develop their tinctorial power. These dyestuffs are so named because of their affinity for cellulose fibers. As a class, the direct dyestuffs have less tinctorial power than the basic dyestuffs; but, in all cases, they

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[1] A **lake** is an insoluble color compound.

are much faster to light than the basic dyes, and, in some cases, than the acid dyes. Some direct dyestuffs are sensitive to hard water, some of the members of this group being precipitated in the form of insoluble lime or magnesia salts.

Direct colors are best dyed at about 140°F. with the addition of salt (sodium chloride) to exhaust (*i.e.*, absorb or use up) the color more freely. Although this procedure is used in mills making blotting papers, it is very seldom resorted to on sized papers, because of the effect on the sizing of the finished sheet. Because of their property of having a direct affinity for the fiber, even though these dyestuffs are generally used for unsized papers, the backwaters[1] in such cases are not always perfectly clear: but they may be cleared by adding a small amount of alum. However, alum has the property of decidedly deadening the shade of all direct dyestuffs; and it is for this reason that the shade produced with a particular dyestuff will be different on sized and unsized papers.

14. Sulphur Dyestuffs.—The **sulphur dyestuffs** derive their name from the fact that sulphur has a predominate part in their manufacture. They are insoluble in water, but are soluble in alkaline sodium sulphide, in which the dyestuff is reduced. This reduced form adheres to the cellulose fiber, and it is oxidized upon exposure to the air, to form the color desired. The only asset of sulphur dyestuffs is their cheapness; but, with the exception of a very few isolated cases in the manufacture of heavy black shades, the decrease in the initial cost of the dyestuff will not offset the greatly increased cost of manipulation. While important to the textile industries, the use of sulphur dyestuffs in the paper trade is practically negligible at the present time.

15. Vat Colors.—The **vat colors** are pigments[2] that are prepared by special processes from the aniline dyestuffs themselves. These pigments are, for the most part, fast-to-light colors that are used almost exclusively in tinting higher-grade white papers. For example, ponsol colors for paper (called indanthrene colors before the war) are a special form of the insoluble textile dyestuff of that name. These colors are the fastest known. On account

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[1] The water that drains off from the fibers during formation of the paper on the machine wire.

[2] A **pigment** is a solid which, on being reduced to a powder and mixed with a vehicle, can be used as a paint or a dye. A pigment is insoluble in the vehicle, while a dye is dissolved in it. Most pigments are inorganic compounds. In coloring paper, they are sometimes added in the dry state.

of being so much faster to light than the majority of the stocks, they should never be used in paper that contains less than 50% rag unless certain properties of the finished paper must be obtained; for, as will be shown later, there is no need of using, in a paper, dyestuffs that are more permanent than the stock from which the paper is made. Other types of pigment color made from aniline dyestuffs include heliopont colors, solar blues, etc. In all these cases, the dyestuffs are used as pigments, and they may be thrown into the beater in the dry state or in water suspension.

PIGMENTS

16. Classification of Pigments.—There are no general rules for the nomenclature or classification of the various pigments now in use in the paper industry. Each pigment is a separate and distinct chemical compound; hence, those here mentioned will be treated individually.

As a rule, pigments are very low in tinctorial power, and they have the disadvantage of lowering the strength of the paper in which they are used; but they increase the weight of the paper, which is sometimes an advantage. Some pigments have the advantage of very low cost, and some are characterized for special purposes by great permanence in resistance to light and chemicals. Pigments also act as fillers to a certain extent, giving, in certain cases, those special characteristics to the sheet that may be desired in it.

The chief types of pigments used in the paper industry are ochers, siennas, umbers, red or iron oxide, chrome yellow, Prussian blue, ultramarine, sap brown, and lamp black. Pulp colors, and certain pigments used in the coloring of coated papers, will be discussed later.

18. Ochers.—**Ochers** are natural silicates that contain ferric oxide or hydrated oxide of iron; they range in shade from yellow to brown, depending on the degree of hydration. Ochers are marketed as finely divided powders, the degree of fineness having a direct bearing on the quality of the product. Freedom from grit is an important factor in the use of ochers.

19. Siennas.—**Siennas** are natural silicates that contain manganese oxide. The range of shade of the various siennas is much the same as is that of the ochers.

20. Umbers.—Umbers are complex silicates that contain a high percentage of manganese oxide and ferric hydrate. Umbers are a greenish brown in their natural state; but, on burning, they become a rich, deep brown, which produces a desirable brown shade on paper.

21. Iron Oxides.—Red oxide, oxide of iron, or **Venetian red** are pigments that depend on ferric oxide or ferric hydrate for their coloring power; they are used to some extent for the coloring of red sheathing, cheap roofing, and a few paper specialties. The use of this product depends a great deal on its quality; for high-grade papers, it must be very finely divided and free from grit. A great disadvantage to the use of these oxides is the dulling action on slitter and cutter knives, and the weakening of the finished sheet, which is caused by the excessive loading required to obtain shades of average depth.

22. Chrome Yellows.—Chrome yellows of various shades, ranging from a bright greenish yellow to an orange, are manufactured by mixing lead acetate with sodium or potassium bichromate. Chrome yellows are usually found on the market in the form of a paste, a generally accepted shade being used under the name of *canary paste*. They can also be made directly in the beater, by mixing lead acetate with the stock and adding sufficient sodium or potassium bichromate to precipitate the lead as chromate. Chrome yellows are comparatively fast to light, but are very sensitive to heat and acids, which makes it difficult to maintain a uniform shade throughout a run, owing to variation of temperature in different beaters.

23. Prussian Blues.—Various **Prussian blues,** both in the soluble and insoluble form, are used for coloring. They are made by the precipitation of ferric sulphate with potassium ferrocyanide. The soluble form of Prussian blue is obtained by boiling the precipitate obtained by the reaction of ferric sulphate and potassium ferrocyanide in an excess of ferrocyanide solution. Prussian blue is an economical color to use, and it possesses very good fastness to light. It has two disadvantages; namely, it is very sensitive to alkali, and it appears greenish under artificial light. Soluble Prussian blue must not be confused with the extensively used aniline dyestuff known as soluble blue or acid blue.

24. Ultramarines.—**Ultramarines** of various shades of blue, from greenish to reddish tone, are used for the tinting of higher grades of white papers. They are soluble silicates of sodium and aluminum, containing some sodium sulphide, made by admixture of sodium carbonate, sodium sulphate, clay, sulphur, silica, and charcoal. After heating to a molten mass and cooling, the mixture is finely ground and washed. Ultramarines have the decided disadvantage of being sensitive to acids and alums. The so-called alum-resisting ultramarines are superior for use in the paper industry. The greater the percentage of sulphur and silica in the ultramarine the redder in tone and the more resistant to alum it becomes.

25. Sap Brown.—**Sap brown,** a brown coloring agent of unknown composition, has a limited use in cheaper grades of paper. It is used more as a dyestuff than as a pigment, due to the finely disintegrated state of its particles in solution. It has the advantage of being fast to light, but it is sensitive to hard water. On account of its non-uniformity, difficulties are experienced in maintaining uniform shades.

26. Paris Black.—**Lamp, carbon,** or **Paris blacks,** produced as soot by the incomplete combustion of various oily organic compounds, are used to some extent for the production of gray or black papers. Lamp black, when used in large amounts, has a tendency to streak the paper; it makes paper rub badly, and it is a decided nuisance in the beater room. Due to its fine state of division and low density, it is apt, through careless handling, to get into the air and settle, in the form of soot, on other material in the beater room; however, this can be avoided by careful handling. The lamp black either can be weighed into a paper bag, and the whole bag thrown into the beater, or it can be made into a paste with hot water. It is difficult to obtain uniform results with lamp black, because the depth of the shade depends on the length of time and manner of beating.

SOURCES AND MANUFACTURE OF ANILINE DYES

27. Source of Coal Tar and Crudes.—Aniline dyestuffs are manufactured from coal tar, which is a by-product of gas and coke making. The percentage of coal tar obtained depends on the method of distillation of the coal. The average production

from one ton of coal is, approximately, 12,000 cubic feet of gas, 1200–1500 pounds of coke, and 120 pounds of coal tar.

28. Crudes.—Coal tar contains several different crudes, the most important of which are benzene, toluene, xylene, phenol, naphthalene, and anthracene, and these are separated from one another by fractional distillation. Each crude forms the starting point from which certain intermediates of importance to the dyestuff manufacturer are made. The residue, or **pitch,** which is left after the crude of highest boiling point has been distilled, is used for paving, roofing, and for other similar purposes. After separating the crudes into groups, each group is further purified by additional distillation or crystallization, and it is then ready to be used in the manufacture of intermediates.

29. Manufacture of Intermediates.—The coal tar intermediates may be divided into three groups; namely, benzene intermediates, naphthalene intermediates, and anthracene intermediates, all of which are derived by subjecting the purified crudes to various chemical operations, such as sulphonation, nitration, reduction, oxidation, fusion, and condensation. The yields and purity of the intermediates formed during these operations are greatly influenced by temperature, pressure, concentration, and other factors. By varying the foregoing operations, and the conditions under which they are conducted, a large range of intermediate compounds is obtainable.

30. Azo Dyes.—The scope of this work will not permit of a detailed account of the different processes entailed in the manufacture of intermediates and dyestuffs; but to exemplify the nature of such operations, the following description of one of the most important types of reaction is given. Most of the direct, a large number of the acid, and a few of the basic dyestuffs are called **azo dyes,** because of the nature of the reaction that takes place in their formation from the crudes into the finished dyestuffs.

31. Diazo Dyes.—When a benzene or naphthalene intermediate containing an amino (NH_2) group is treated with sodium nitrite and hydrochloric acid at a temperature around 5°C., a process known as **diazotization** takes place. The amino group of the intermediate reacts with the nitrous acid in such a way as to form a **diazo** compound (see Section on *Elements of Chemistry,* Vol. II, Art. **243**), which will readily unite with other intermediates, forming a series of dyestuffs, according to the

substances so combined. Since there is an endless number of intermediates that may be diazotized, and since there are just as many more with which the resulting compounds may combine, it can readily be perceived that an enormous number of dye-stuffs can be formed by substituting different intermediates. Proceeding a step farther, the intermediate with which the diazo compound combines may possess an amino group that is also capable of being diazotized and combined with a third body. In many dyestuffs, four intermediates are thus linked up; in some cases as many as five are employed.

32. Manufacture of Vat Colors.—While the vast majority of basic, acid, and direct dyestuffs are made from benzene and naphthalene intermediates, the vat colors are made from the anthracene intermediates by certain processes of sulphonation, causticization, fusion, etc. These are the most difficult dye-stuffs to manufacture, because very slight variations in manufacturing conditions produce entirely different results. The **vat dyestuffs** are so ca'led because they must be reduced in an alkaline solution before applying to the cellulose fibers. Since they are the fastest to light of all known dyestuffs, and since reduction is not possible during the manufacture of paper, these colors are prepared in a special form for the use of the paper industry by reducing to the leuco-compound (or colorless form) in an alkaline solution with caustic soda and glucose, at high temperature, and re-oxidizing in the air, to form pigments of a very fine degree of subdivision.

STANDARDIZATION OF DYESTUFFS

33. Importance of Standardization.—More important to the consumer of dyestuffs than the details concerning their manufacture is the standardization of the finished product. In order to color the paper uniformly, the beater engineer must decrease the number of variables with which he has to contend. He must be assured that when he has once secured a color formula for a given furnish, every barrel of the dyestuff he receives under a given name or designation shall be absolutely uniform with respect to strength and shade.

34. Methods of Standardization.—In the manufacture of paper, it is a physical impossibility to hold the basis weight

absolutely constant; likewise, in the manufacture of dyestuffs, it is impossible for every run of the crude dyestuff to be of exactly the same strength and shade. For this reason, a standard of strength and shade for each individual dyestuff is adopted by the manufacturer, the strength of this standard being slightly less than the average strength obtainable in the crude product, or *crude charges*, as they are called. All dyestuffs, after being filtered and dried, are ground to a fine state of subdivision, and are compared in strength and shade with the standard adopted by the manufacturer. One charge, for instance, may be slightly redder than the standard, while the next may be slightly greener; different lots are mixed together with varying amounts of the standardizing agent, to produce the finished dyestuff, which is exactly the same in strength and shade as the standard adopted by the manufacturer.

35. Standardizing Agents.—The standardizing agent most used for basic dyestuffs is dextrine, while common salt $NaCl$ or Glauber's salt $Na_2SO_4.10H_2O$ is used for acid and direct dyestuffs. Other standardizing agents used in isolated cases are sugar, sodium phosphate, and soda ash. An erroneous impression prevails among certain consumers that dyestuffs containing any of the chemicals just mentioned are more or less adulterated. However, a little reflection will show that this is the only way by which the absolute uniformity of every product can be controlled by the dyestuff manufacturers, and that the selection of a standardizing agent is so made as not to interfere with any subsequent operations of paper manufacture.

36. Reduced Brands.—The practice of adding a standardizing agent to the dyestuff is sometimes abused by unscrupulous concerns, which make large profits by reducing the strength of the standard brands of the manufacturers; this is one cause for the excessive number of dyestuffs of varying concentrations and shades on the market, and it results in a great deal of confusion to the consumer. These are known as **reduced brands;** and whenever such dyestuffs are placed on the market, a definite comparison of their strength with that of the concentrated brands of standard manufacturers should be given. In certain cases, reduced brands work more efficiently in the mill than the concentrated brands, especially where small quantities must be weighed. An example of this is the case of rhodamine B extra

and rhodamine B, the former being five times the strength of the latter. The latter is more generally used in the paper industry, because of the great strength of the rodamine B extra, which makes the weighing of the concentrated form, in tinting white papers or for shading, practically impossible, within the degree of accuracy that must be maintained. Until the reliability of the source of supply is established, laboratory tests should be made on the product samples submitted and, also, on all supplies of dyestuffs received.

37. Mixtures of Dyestuffs.—Mixtures of dyestuffs are made by all dyestuff manufacturers, and they are sold to the trade under either a given name or under a mixture number. They are made by combining two or more dyestuffs to produce a particular shade, by mixing them, together with a standardizing agent, in a standard mixer. Efficient paper-mill practice has proved that, except in special cases, the use of mixtures should be avoided whenever possible. The principal exception to this rule is in the use of mixtures of methylene blue and methyl violet for the tinting of the cheaper grades of paper, such as newsprint; but, even in this case, the authors of this Section consider it to be the best practice to use the individual dyestuffs, in order to shade back and forth in the mill, because of the variation in stocks during different parts of the year.

38. Theories of Dyeing.—Among the various theories of dyeing that have been advanced are the mechanical theory, the chemical theory, the solid solution theory, and the adsorption theory. A full discussion of this subject is not advisable in this work; but, for information concerning these theories or for further information on the manufacture of intermediates and dyestuffs, the reader is referred to the various books on dyestuff manufacture and on textile dyeing, such as: Erfurt, *The Coloring of Paper;* Mathews, *The Application of Dyestuffs,* and the literature of dyestuff manufacturers.

TESTING OF DYESTUFFS

THE LABORATORY

39. The Work of the Laboratory.—The laboratory work in connection with the testing of dyestuffs should be divided into four general groups: first, a test for strength and shade on all

samples of competing products submitted by manufacturers; second, a laboratory check on material received against standard samples, to determine whether the dyestuff being tested is standard in strength and shade; third, laboratory tests to be made to determine the composition of mixtures of dyestuffs and the chemical identity of individual dyestuffs or mixtures; fourth, the approximate matching of mill shades, as a guide to subsequent matching in the mill.
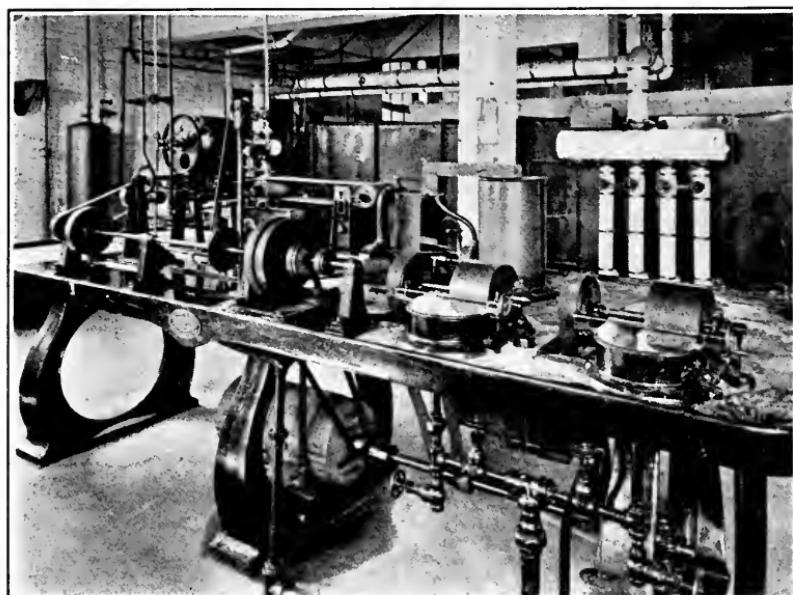
FIG. 1.

Fig. 1 (see "Equipment," Arts. **40, 41**) shows the operating bench, on which is mounted the equipment necessary for producing a continuous sheet of paper. This consists of a motor, mounted on a frame below the table and driving directly the two small beaters that are shown on the table. From the countershaft at the left of the table, a belt drives the small pump that is used for circulating and agitating the stock in the stock chest, or for delivering the stock into the head box. The stock is delivered from the head box to the vat of the paper machine. A belt also drives the small white-water pump, whose delivery is shown coming over the edge of the head box, and which is controlled by a valve. The paper machine consists of the vat, in which turns a mold covered with wire cloth, and over which travels the felt that picks up the paper deposited on the wire. The felt transfers the paper to the large drying cylinder, shown at the far left, to which the paper sticks and by which it is dried and given a finish. The last belt from the countershaft drives this dryer through a worm gear. The small beaters are driven direct from the motor shaft. By matching shades on a miniature machine of this kind, actual machine conditions, such as return of white water, drying temperatures, etc., are approximated.

40. Laboratory Equipment.—In addition to the general equipment that the ordinary laboratory has, consisting of chemical glass and porcelain ware, burettes, graduated cylinders, pipettes, beakers, volumetric flasks, distilled water, hot plates, etc., the

following equipment is necessary for the special work in connection with the testing of dyestuffs:

(1) Miniature beater of from $\frac{1}{4}$ pound to 5 pounds dry stock capacity, the size depending on the amount of testing to be done. A washer on such a beater is of decided advantage.

(2) A small screen, to be used to thicken the pulp from the beater. This screen can be conveniently and cheaply made by cutting the bottom from an ordinary galvanized-iron pail and
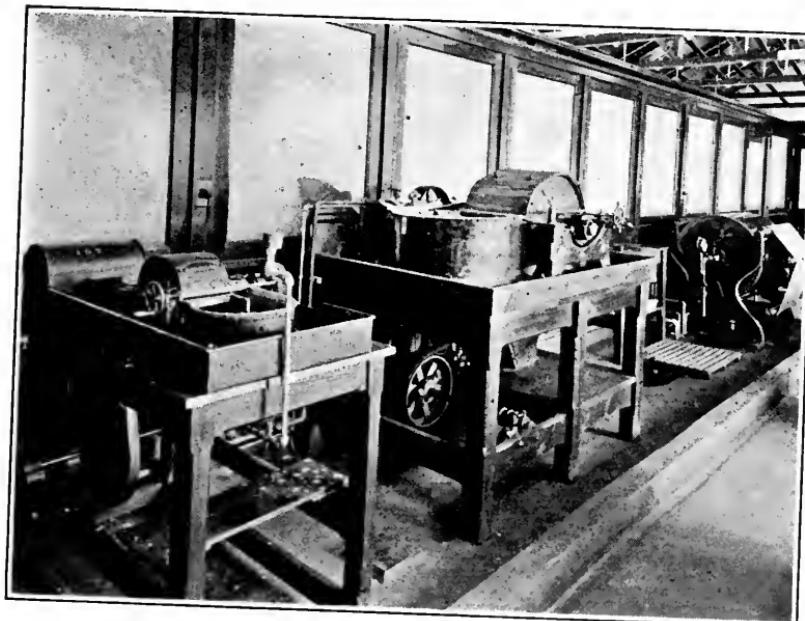
Fig. 2.

Fig. 2 shows two laboratory-size beaters and a cylinder for drying test sheets. The small beater will hold about $\frac{1}{2}$ pound of paper pulp, and the large one about 8 pounds. In either beater, the pressure of the roll on the bed plate can be adjusted by a mechanism similar to that used on the regular mill beaters. Wood pulp or rag stock is placed in the beaters, and in the same proportions as were specified by the mill for the paper whose color is to be matched. The proper percentages of sizing and loading materials are also added, and then a standard solution of the dyestuffs is introduced in successive quantities until exactly the right shade is secured, as indicated by comparison with the test samples. When the proper shade has been obtained, the pulp is made into sheets by means of a sheet machine, and it is then dried on the drying cylinder shown in the illustration. This cylinder is fitted with a felt, and with a steam inlet and a siphon water outlet, like a paper-machine dryer. As shown in the illustration, the steam line carries a pressure gauge. The larger beater is used when a large number of samples are required, or when it is necessary to get a more vigorous beating action than is possible with the smaller beater. These beaters may also be used as supplementary to the equipment shown in Fig. 1. Each machine is driven independently by its own electric motor.

covering it with a piece of paper-machine wire, or by merely fastening a piece of paper-machine wire to a wooden frame.

(3) Five gallon crocks, with covers, for storing moist pulps.

(4) A set of power-driven stirrers, to stir the mixture of pulp, color, size, and alum. In case the amount of work of this type that needs be done is limited, and the cost of installing such a set of power-driven stirrers is not warranted, the writer has found several types of egg beaters on the market that are very suitable for this work.

(5) A suction pulp mold or funnel, made from heavy sheets of copper, in which paper-machine wire is tightly stretched. This
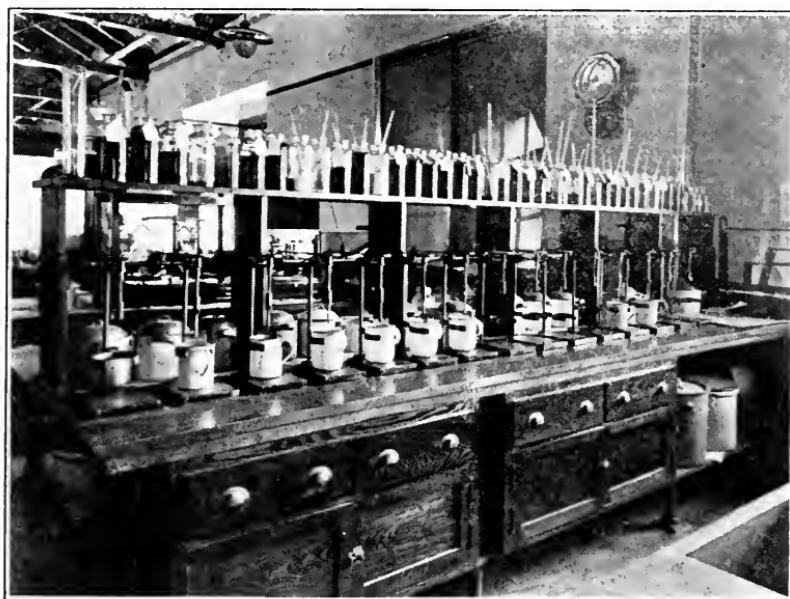
FIG. 3.

Fig. 3 shows two of the work benches in the color laboratory. On the bench in the rear are seen the handles of a receptacle for keeping samples of beaten pulp. Large quantities of pulp can be weighed on the big scales, while small amounts of dyestuffs, or dried sheets of paper, can be weighed very accurately on the delicate balances that are shown farther down the bench. A letter press, used for flattening sheets, can be seen at the end of the bench. On the bench, in the foreground, are the receptacles for the standard pulps required, and the mixing cups for matching shades. It will be noticed that the agitators in these cups are driven by a countershaft, which runs the length of the bench and is driven by a small electric motor. Above the bench are the jars and bottles containing the various dyestuff solutions, and the rosin, alum, starch, clay, and other materials that may be required in making certain papers. It is necessary to approximate, in so far as is possible, all conditions and factors of furnish and manufacture.

wire should be reinforced with a coarser copper-wire screen, supported by a perforated copper plate. The neck of the funnel should be fitted with a rubber stopper, so arranged that it can be mounted either in a suction flask or, preferably, in a large copper receptacle, fitted at the bottom with a stop cock, to allow the back waters to drain away when the box is not in use. An

advantage in using the suction flask is that the color of the back waters can easily be seen, which permits an estimation of the retention of the dyestuff by the paper. Suction may be obtained by the ordinary water-suction pump or by means of a small vacuum pump, connected to a large intermediate vacuum chamber in order to secure a constant suction when the mold is in use.

FIG. 4.

Fig. 4 shows a recently developed sheet machine. It consists of a piece of Fourdrinier wire, supported and held flat by a frame on a leg, and so adjustable that it can be made level, and of a box (tipped back in the illustration), which makes a water-tight, machined fit with the frame. A plug valve below the frame (which forms a box) controls the drainage of the water from the stock, which is allowed to become quiescent before being drained.

(6) Several thicknesses of old canvass dryer felt, cut about 16 inches square, to be used with filter paper and blotting paper to couch the sample.

(7) A dryer, with a revolving drum from 1 foot to 4 feet in diameter, made of copper or bronze, either steam or electrically heated, together with a motor for revolving the drum, so the paper sheets are carried in between the surface of the hot drum and the dryer felt.

(8) A supply of one-quart white-enameled cups and of wide-mouth glass bottles.

(9) A rough balance, sensitive to 0.01 gram, for weighing pulps; this balance is in addition to a chemical balance for weighing to 0.0001 gram.

41. Additional Laboratory Equipment.—There is practically no limit to the additional expenditures that can be made for laboratory equipment. There are miniature paper machines on the market, ranging in size from 4 inches to 30 inches trim, which approximate the larger paper machines in the majority of details. Other pieces of experimental equipment used in laboratories for special purposes are available. Among these may be mentioned a tissue-dyeing machine, so arranged that the paper passes through a color box and squeeze rolls, to remove the excess of color; and a miniature two-roll, three-roll, or four-roll calender stack, equipped with water or color boxes, for making experimental runs on calender coloring.

SEPARATION OF DYESTUFFS INTO GROUPS

42. Identification of Coloring Matters.—The identification of various coloring matters requires considerable experience and patience in studying the color reactions by which they are identified. To investigate this question thoroughly, requires years of experience. However, since all large dyestuff manufacturers operate a technical service department in which men who have made this problem a life study are employed to handle this work, the paper manufacturer will obtain more satisfactory results by depending on the dyestuff manufacturer for information on any dyestuffs he wishes to have identified.

Nevertheless, a general knowledge of the separation of dyestuffs into their various groups, and of the tests of behavior toward different chemicals, is important to the paper manufacturer; it enables him to generalize his information, and it assists him in making paper that will meet special requirements.

43. Separation of Aniline Dyestuffs and Pigments.—The first step is to determine whether the coloring matter under consideration is a soluble aniline dyestuff or a pigment. The pigment colors may be easily identified as a class by their insolubility in water, soluble prussian blue being the exception to this rule. The pigment colors used in the paper industry being few

in number, and possessing certain characteristics of appearance, tinctorial power, etc., are comparatively easy to identify.

If the coloring matter is soluble in water, the following procedure should be adopted to determine: first, whether the dyestuff is a single color or a mixture; second, to what group it belongs; third, to determine, if possible, the individuality of the dyestuffs in its particular group.

A small amount of the dyestuff is placed on the point of a knife or spatula, and is gently blown onto a piece of wet pulp or filter paper; this action is called a **blowout.** If the dyestuff is a mixture, the sample is separated into its component parts, each individual particle showing a **spot** of different color.

44. In some cases, where the sample being tested is a mixture of two dyestuffs somewhat similar in shade, it may be difficult to distinguish the component parts from a blowout on wet pulp or filter paper. As a check to the above method, a small amount of the sample is placed on a blade or spatula and blown onto the surface of about 10 c.c. of sulphuric acid, contained in a small porcelain evaporating dish. Different dyestuffs give different color reactions with sulphuric acid, thus indicating at once whether the sample is an individual dyestuff or a mixture.

45. Determination of Mixtures.—Some dyestuffs are mixtures obtained by evaporating to dryness solutions of two coloring matters that have previously been thoroughly mixed. Such a mixture can be determined by making successive dyeings on skeins of plain cotton, tannin-mordanted cotton,[1] or wool, depending upon whether the mixture has been determined to be a basic, acid, or direct dyestuff. If the color is a single dyestuff, the skeins made by a series of dyeings to exhaust the bath, will show a gradual shading down in strength of the same shade. If the dyestuff is a mixture, then the first and last dyeings will differ in shade. Allowance must be made for the variations in strength of the different dyeings, as such variations often cause an apparent variation in shade.

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[1] Tannin-mordanted cotton can be prepared by inserting boiled-out cotton yarn into a bath containing 3% tannic acid, based on the weight of the yarn, at 140°F. Raise the temperature of the bath to 200°F., and hold for one hour. Steep until next morning, when the yarn should be wrung out and dried, but not washed. Dissolve 1% to 1½% tartar emetic in water, introduce the dried yarn at 100°F., hold one-half hour, wash, and wring evenly.

46. Separation of Aniline Dyestuffs into Groups.—The second question to determine, if the sample has been shown to be an individual dyestuff, is to what group it belongs. Only basic, acid and direct dyestuffs, and pigment colors, are used in the paper industry, and tests for those groups only will be necessary. As previously stated, pigment colors can be identified by their insolubility in water, as indicated when a blowout is made on wet filter paper to determine whether the color in question is a mixture.

47. Method of Testing.—Prepare in a test tube a dilute solution of the dyestuff; after adding a few drops of acetic acid, insert a thread of boiled-out degreased wool and one of tannin-mordanted cotton. If the tannin-mordanted cotton is dyed, a basic color is indicated; if the wool is dyed, an acid or direct dye is indicated.

In a second test tube containing a dilute solution of the dyestuff, add a small amount of Glauber's salt; place a cotton thread in the test tube and warm the solution. To determine whether the thread was actually dyed or merely mechanically colored, remove the colored cotton thread and place it in another test tube that contains distilled water, and boil. If the cotton retains its color, the results indicate that the sample being tested is a direct, or substantive, dyestuff.

If the sample under examination colors both the wool and the tannin-mordanted cotton, repeat the dyeing test in a very dilute solution of the dyestuff, to which acetic acid has been added. If the sample is an acid dyestuff, it will color the wool; but, if it is basic, it will stain only the tannin-mordanted cotton. To substantiate the basic character of the dyestuff in the latter case, add some tannic acid to a separate fresh solution of the dyestuff, to which has been added some sodium acetate; if the sample is a basic dye, a precipitate of tannin lake will occur.

48. Subsequent Steps.—The subsequent determination of the individuality of the sample submitted is a process of analytical character that requires a long training. To become efficient in these methods of determination, which are based upon the reactions of the different dyestuffs with weak and strong alkalis, weak and strong acids, reduction, and oxidation, would require more time and labor than the paper manufacturer or the paper-mill chemist could devote to it. As stated before, the dyestuff

manufacturers have men trained to do this work; and, in all cases where the actual identification of the sample is required, the sample should be submitted to the technical laboratories of the dyestuff manufacturers.

<div style="text-align:center">OTHER TESTS</div>

49. Testing for Strength and Shade.—The testing of a given dyestuff for strength and shade is more important than its identification, because such tests show the actual money value of the dyestuff to the consumer. All work in the laboratory should be done on the same stock as that to be used on the run of paper for which the particular formula is being worked out. The number of pulps kept on hand in the laboratory depends on the grades of paper made in the particular mill. A laboratory doing work for a mill making numerous grades of paper should carry the following pulps in stock: unbleached sulphite (quick cook), unbleached sulphite (Mitscherlich), bleached sulphite, kraft, soda, groundwood, cotton linters, and rag stock.

50. Preparation of Stocks.—These stocks are prepared for laboratory use by one of two methods. If the stock is to be prepared in the laboratory, it is placed in the miniature beater, where it is beaten until it gives the proper feel or *freeness test* (see Sections on *Refining and Testing of Pulp*, Vol. III, and *Beating and Refining*, Vol. IV). The excess of water is then removed by means of a suction funnel or a laboratory pulp thickener. The pulp is next placed in a crock, and it is kneaded until the moisture present is evenly distributed; the crock must be kept tightly covered at all times. In some cases, it is easier to take the stock directly from the beater room, before the size and alum have been added to the mill beaters; and, after removing the excess of water, the same procedure is followed as with the laboratory-beaten pulp.

51. Moisture Determination.—Moisture determinations should then be made, to ascertain the weight of wet pulp that will be necessary to make a hand sheet of a required air-dry weight. These moisture tests are in constant use, and the moisture content should be accurately determined at frequent intervals. The basis weight for pulp to be used for hand samples varies in different mills, but an average of $2\frac{1}{2}$ grams of air-dry pulp will make a 6-inch diameter hand sheet of average thickness.

The moisture content of the prepared pulps should be of such a consistency that from 10 to 15 grams of the wet pulp will be equivalent to $2\frac{1}{2}$ grams of the dried pulp. Certain pulps, such as jute, manila, kraft, groundwood, and old newsprint, are readily attacked by mold and bacteria. When fermentation or bacterial change occurs, as indicated by the color or odor of the pulp, it is advisable to prepare a new supply.

52. Approximate Methods.—For straight color evaluation work, either unbleached sulphite or mixtures of equal parts of unbleached sulphite, soda, and groundwood are used; which to use depends, of course, on the grades of paper made at that particular mill.

The dyestuff to be tested should be made up into a standard solution, by weighing out on an accurate balance, dissolving in hot water in a casserole, and, after solution is complete, pouring into a volumetric flask and making up to the proper volume. A convenient strength for these solutions is 0.5 gram of dyestuff per liter.

53. For matching a product sample of dyestuff against a standard sample, to determine the strength and shade, the following approximate methods are suggested:

(*a*) Before the solutions are made up to the required volume, spot each of the solutions side by side on a filter paper. Note the difference in strength, and increase the volume of one of the stronger dye solutions (*i.e.*, dilute it) to the point where further tests show the solution to be of equal strength with one of the weaker ones. By comparing the volumes of the two solutions, an approximation to their relative strengths can be made, which will save the time required for determining the actual strength test by making hand samples.

(*b*) Another approximate method, known as the *dip test*, is made by cutting a piece of heavy filter paper in such a manner that it will have two equal legs or forks. The standard solution and that to be tested are then placed side by side, one leg of the filter paper being dipped into each of the two solutions. Upon examining the filter paper after drying, an approximation to the relative strengths can be obtained.

54. Standard Solutions.—In addition to the color solutions, which should be made up fresh as required, the following standard solutions should be kept on hand at all times; namely, size, alum, soda ash, and clay. For laboratory work, a convenient

strength of the solutions of the first three items is $2\frac{1}{2}\%$; the suspension of clay should be approximately 20 parts of water to 1 part of clay, and the bottle containing it should be thoroughly shaken each time before using. The following description gives the methods and relative proportions used very successfully in one laboratory, and they can be used as a guide for other laboratories:

55. On a rough balance, weigh out the samples of wet pulp, equivalent to 2.5 grams air-dry weight, and place in a porcelain-lined cup. Add 50 to 100 c.c. of water, and mix the stock for 5 minutes by means of the mechanical stirrers or paddles mentioned in Art. **40.** At five-minute intervals, add the color solution, size, and alum; if fillers be used, they should be added at a five-minute interval before the size. After all material has been added to the cup, and the total stirring time is equal to 39 minutes, add approximately 500 c.c. of water, stirring continuously for a minute or more.

56. Making Hand Samples.—The diluted pulp is now poured into the funnel or mold, and the suction is applied. If a suction flask be used, it is rotated, finally, at an angle that will completely remove the water that tends to adhere to certain portions of the sheet of pulp. The suction is then turned off, and the sheet is carefully loosened on one side by means of a spatula. The sheet is then lifted from the wire and placed between two sheets of filter or white blotting paper. If an ordinary rolling pin be used to couch the sample, the sample sheet and blotting (or filter) papers should be placed between pieces of ordinary dryer canvass. If a wringer is to be used, the amount of blotting or filter paper should be doubled, as the sample, covered by this paper, is passed through the wringer. The remaining moisture should be removed on drying on the rotary drum dryer (Art. **40**) or on a hot-plate. When drying these hand samples on a drum dryer, the sheet should be reversed after every revolution of the drum, to hasten the drying and to avoid the danger of burning the color to the surface.

57. Color Formulas.—All color formulas should be given in terms of 1000 pounds of stock. When the above-mentioned proportions of 2.5 grams of air-dry pulp, a color solution of 0.5 gram per liter, and 2.5% solutions of size and alum are used, every 5 c.c. of color solution is equivalent to 1 pound of dyestuff per 1000 pounds of stock; and 1 c.c. of size or alum is equivalent to 10

pounds of that material per 1000 pounds of stock.[1] When testing individual dyestuffs against a given standard for strength and shade, a 0.2% dyeing is recommended for basic dyestuffs, and a 0.4% dyeing for acid and direct colors; *i.e.* add 10 c.c. and 20 c.c. of dyestuff, respectively, to the pulp.

58. Strength of Yellow Dyestuffs.—For determining the strength of yellow dyestuffs, small standard amounts of either methylene blue or of safranine are added to the stock of both the standard and the product sample dyeings. A greenish tint is produced, which registers more distinctly than yellow on the eye. The strength of the yellow dyestuff is then determined by the degree of shading toward the true shade of either the methylene blue or the safranine.

FASTNESS TESTS

59. Varieties of Fastness.—For every grade of paper, those dyestuffs should be selected which will give the most economical match, consistent with the quality to be maintained. In certain papers, fastness to (resistance to change by) light is the important quality; while in others, fastness to alum, acid, or alkali may be the properties required. Fortunately, the paper industry does not have as many fastness tests to which the dyestuffs must be subjected as will be found in the textile industries. With a few exceptions, fastness to light, acid, alkali, heat, and chlorine are the only tests necessary in the selection of dyestuffs for paper.

60. Fastness to Light.—The first important fact to consider in making a test for fastness to light is that all stocks are discolored in the sunlight with varying degrees of rapidity; and any discoloration that may be due to exposure should be followed through, to determine whether the change in color is due to the pulp, to the dyestuffs, or to, perhaps, a combination of both. Bonds, ledger, cover papers, and wall papers are grades where fastness to light is important. These papers are exposed, in the course of their use, to varying degrees of sunlight, and a dyestuff should be selected whose fastness to light approaches as nearly as is possible to the fastness of the pulps from which the paper is made. In newsprint, wrapping papers, and cheap grades of book

[1] 0.5 g. dye stuff per liter (practically = 1000 g.) = 0.0005 g. per c.c. 5 c.c. = .0025 g. and .0025 [g. dye per 2.5 g. pulp = 1 g. to 1000 g. or 1 lb. to 1000 lb. 1 c.c. alum, etc. = .025 g. per 2.5 g. pulp = 10 g. per 1000 g. or 10 lb. alum, etc. per 1000 lb. pulp.

and magazine papers, there is never any need to sacrifice cheapness for fastness properties. Consequently, in all papers where groundwood (which discolors rapidly in sunlight and is naturally dull in appearance) is used, basic colors should be adopted, because of their low cost and extreme brilliance.

No paper can be colored with organic dyes so it will be absolutely fast to sunlight. Certain pigments, chief of which are those derived from the vat colors, possess the greatest fastness, while the acid, direct, and basic dyestuffs follow in this order.

61. Tests for Fastness to Light.—There are several ways in which fastness-to-light tests can be made. Exposure to direct sunlight is the most conclusive test, but it is difficult to obtain definite comparative results by this method, because of the varying degree of brightness of sunlight at various times of the day or year. Laboratory tests may also be made means of a fadeometer or an ultra-violet lamp. When comparisons are to be made between two different dyestuffs or between two different stocks using the same dyestuff, the several dyeings should be exposed to the rays of these lamps at the *same* time; because, even in the laboratory, the conditions affecting the heat and strength of the rays emitted by the lamps vary to a certain extent.

For reasons just explained, no numerical values as to the comparative fastness of all dyestuffs is possible. All comparisons must be relative; for which reason, it is recommended that dyestuffs be divided into five general groups, when making such tests, rather than to try to classify them in a numerical order based on percentages.

62. Fastness to Alkali.—Fastness to alkali is important in such papers as soap wrappers, wall papers, and box cover papers, where alkaline pastes are used, or for any type of wrapping papers that are liable to come into contact with alkaline materials. A spot test, with $\frac{1}{2}\%$ solution of caustic soda or 2% solution of soda ash, is sufficient for commercial purposes. Fastness to alkali is also necessary in ledger and bond papers, so they shall be fast to chemical erasures. For testing the fastness against chemical erasure, laboratory samples of the paper, made with the dyestuff material being examined, should be spot-tested.

63. Fastness to Acids.—For dyestuff tests on fastness to acids, colors may be divided into three groups: The first group includes those dyestuffs which are unaffected by alum or a 1% solution of

sulphuric acid; the second group includes those which are affected by alum and sulphuric acid; the third group includes those dyestuffs which are affected by a 1% solution of sulphuric acid, but are not altered by alum.

All direct dyestuffs are affected in shade by the use of alum and by spot tests of sulphuric acid, being dulled to a considerable extent. Acid colors as a class are fast to acids, one important exception being metanil yellow, which is very sensitive to even a slight excess of alum. Basic dyestuffs as a class are not affected by alum; but no general rule applies as to their reactions with sulphuric acid.

64. Fastness to Heat.—No special laboratory tests are possible that will determine the effect of heat on finished paper, for finished paper is never subjected to heat above a temperature harmful to the dyestuff. Nevertheless, the effect of heat on various dyestuffs during the process of paper manufacture is an important consideration, and a practical knowledge of which dyestuffs are thus affected is essential. When the dryers are somewhat too hot, certain acid dyestuffs seem to be drawn to the surface of the paper, giving a decidedly spotty appearance to the sheet and a difference in the color of the two sides (*two-sidedness*). The uniformity of color throughout the run may be seriously affected by variation of temperature of the dryers. Metanil yellow behaves worst in this respect, especially in the presence of a slight excess of alum. Certain basic and direct dyestuffs give a different shade to the paper when it first comes off the machine from that which prevails when the sheet is cooled. When such dyestuffs are used, allowance for this effect must be made when matching.

65. Fastness to Chlorine.—In paper manufacture, trouble with chlorine is experienced where freshly bleached stock is furnished to the beater. In cases where the stock is so poorly washed that large excesses of chlorine still remain, an antichlor, such as sodium sulphite or sodium thiosulphate, should be added to the stock in the beater, to react with the free chlorine. To determine the effect of poorly washed stock upon certain dyestuffs, two hand samples should be run in the laboratory, to one of which should be added a dilute solution of bleaching powder. It should be remembered that the use of antichlor usually leaves the stock acid.

66. Tests Should Be Comparable.—The above-described tests should be made as comparable to the actual working conditions in the mill as is possible. Where time permits, the dyestuff manufacturer will give information as to the reactions of the dyestuff with various chemicals. In other cases, special tests should be made by the above methods, using actual mill stocks and mill solutions, in order to get the best practical results.

67. Effect of Fillers.—All fillers used in the process of paper manufacture have a certain absorptive power for dyestuffs, the degree of absorption depending on the nature of the filler and also on the relative affinity of the dyestuffs for the pulps and fillers. When the fillers are added to the beater in the presence of dyestuffs, a state of equilibrium is established between the amount of dyestuff absorbed by the fillers and that retained by the pulp. Since some of the filler is lost in the backwaters, there is a corresponding loss in available dyestuff. Concrete information concerning relative absorptive powers of various fillers for individual dyestuffs would benefit the paper maker. Research work on this subject has been started, and the results obtained will be submitted to the paper industry as a Report of the Committee on Dyestuffs.

MATCHING TESTS

68. Matching Shades.—Matching shades in the laboratory, together with subsequent work in the mill, is dependent on the character of the stocks, chemical furnish, finish and the class of dyestuff to be used, as well as on the training of the eye to detect readily slight differences in strength and shade. The pulp and chemical furnish is usually given to the laboratory for the sample of paper to be matched. If not, a microscopic analysis will determine the percentage of various pulps in the furnish; and approximate tests for sizing and loading will determine the proportions of size, alum, and fillers necessary. If the paper sample to be matched be heavily calendered, it should be steamed for a few minutes, to graduate the finish to approximately that of the laboratory hand samples, so the true color of the paper sample can be noted. If the sheet be water finished, allowance must be made for the darkening of the sheet by this treatment. In matching samples of glassine paper, satisfactory results can be obtained only when the highly hydrated pulp used in the

manufacture of this type of paper is obtained from the mill beater; for it is impossible to hydrate stock to that degree in a miniature beater. For a given shade, approximately one-half the amount of dyestuff is required for glassine papers that is necessary for the ordinary dry-finished sheets.

69. When matching any new shades, it is advisable to do the work by daylight, a north light being preferable to any other for this purpose. The various daylight lamps on the market are valuable for matching shades when such work cannot be done in the daytime; but the change of shade of different dyestuffs under artificial light will not hold constant under any daylight lamp at present available.

The general method for preparing hand samples from various stocks and with various chemicals has been previously discussed. When matching shades in the laboratory, the same methods apply as when testing for strength and shade of an individual dyestuff, except that a combination of colors is used to match the given sample.

70. Matching Dyestuffs.—To save time in making laboratory matches, the following procedure should be adhered to in order to approximate the quantity of dyestuffs required to obtain a given shade. After the dyestuff, size, and alum have been added to the stock in a porcelain-lined cup, a small amount of the stock should be taken from the cup, squeezed between the thumb and forefinger, and placed on a hot-plate to dry. On comparison with the given sample, an approximation can be made. A small test sample of this kind should be taken out following the addition of each new furnishing of dyestuff; for, in this way, a close approximation can be reached with one weighing of stock, and time is saved in making finished hand samples. When matching a shade where the quantities of each dyestuff are being varied slightly, care should be taken not only to measure out the dyestuff accurately but also to watch carefully the order of the addition of color, size, and alum and the length of time of stirring.

71. Amount of Dyestuff to Use.—By using the methods described in the last article, the quantity of dyestuff necessary per 1000 pounds of stock can easily be calculated. Experience has shown that, as a rule, the amount of dyestuff required to match a sample in the laboratory is usually in excess of that

actually required in the mill. For this reason, it is recommended that, in all cases where a laboratory formula is to be used in the mill, the first addition of dyestuff to the beater should be only 75% of that called for by the laboratory formula.

72. Cost Comparisons.—The determination of the actual color value of a dyestuff is not always a simple problem. This is due to three facts: first, it is very easy to reduce a particular dyestuff 5% or 10%, in order to meet price competition; but this reduction may not be observed by the paper manufacturer, due to variations in pulps or in mill conditions. Second, in certain grades of paper, it is difficult to estimate the depth of a shade within an accuracy of 10%; this is particularly true in the case of yellow shades on all papers, and to all shades on the cheaper grades of wrapping papers and boxboards. Third, while it is comparatively simple to compare two dyestuffs of the same constitution, such as two methyl violets or two methylene blues, it is difficult for the manufacturer to obtain the actual color value when deciding between a low-cost dye of comparatively poor fastness qualities and a higher-price dye of superior qualities. This problem resolves itself into a broad study of what the consumer of the paper actually wants, and to conditions of efficiency in the manipulation of dyestuffs throughout the process of manufacture. It is worth while, however, to make a laboratory comparison of dyestuffs, and, from the percentages required to give matched samples, to calculate from the price of the dyestuffs, the money value of each in the paper.

PRACTICAL APPLICATION OF DYESTUFFS

COLOR AND BEATER ROOMS

73. Methods of Coloring.—The methods employed in the coloring of paper may be divided into several classes; namely, beater coloring, calender coloring, combination of beater and calender coloring, tub coloring, dipping, specialty coloring by special processes, and coloring of coated papers. Approximately 95% of the coloring of paper is done in the beater; for which reason, the greater part of the remainder of this Section will be devoted to that branch.

74. Color Room Essential.—A well-equipped color room is essential, regardless of the process by which the paper is colored. While slight variations in equipment are necessary in mills doing other than beater coloring, such variations must depend on mill conditions, and they will not be discussed in detail at this point.

Every beater room should have an adjoining color room, to be used for the storage of all kegs and barrels, and for the weighing and dissolving of all dyestuffs. This color room should have a cement floor with two drains; one drain approximately in the center of the room, the other beneath the outlet of a hot-water storage tank. Shelves should be built along one side of the room, for the storage of tins and small containers, and the room should have a wall table, on which the balances are placed.

75. Equipment of Color Room.—A well-equipped color room should contain one rough balance, having a capacity of 20 pounds, weighing to ounces, and a finer balance, having a range from $\frac{1}{32}$ ounce to 2 pounds. The accuracy of these balances should be tested at regular intervals. The authors recommend the ordinary type of computing grocery scale, with a glass top, as best suited to this work.

76. Hot-Water Storage Tank.—A hot-water storage tank, having a capacity of from 50 to 100 gallons, capable of furnishing a constant supply of hot water at a temperature just below boiling, should be available. The best type is equipped with a thermostatic control, which is connected to a steam pipe in such a manner that, when the temperature falls below 200°F., steam will automatically be injected into the tank until the temperature is raised to the desired point, when the steam is shut off.

77. Barrels and Other Containers.—In most cases, the barrels and larger containers are left standing on the floor of the color room. To insure that the dyestuffs are kept dry, it is recommended that a platform be built 2 or 3 inches above the floor, on which to place the barrels. A still better plan is to arrange bins, similar to flour bins, into which the ordinary size barrel will fit; such an arrangement insures a dust-proof storage space in the color room for dyestuffs. If the barrels or kegs of dyestuffs are left open on the floor, the names of the dyestuffs should be stenciled on their sides. It has been the practice of dyestuffs manufacturers to label their containers on the covers. Upon

removing the covers in the color room, they often become misplaced by being set on the wrong barrels. In their powdered form, many aniline dyestuffs have a similar appearance under artificial light; hence, unless the barrels are thoroughly marked on the sides, mistakes are liable to occur that may prove serious.

Copper-lined containers, ranging in capacity from 10 to 25 gallons, are the best for dissolving dyestuffs; but galvanized-iron pails and wooden half-barrels are used extensively for this purpose. Wooden containers, however, have the disadvantage of soaking up a limited amount of the dyestuff when first used, and they are more difficult to clean. Plain iron containers must never be used. Upon emptying the containers, they should be thoroughly cleaned, turned upside down to dry, and thus left in condition for further use.

78. Dissolving Dyestuffs.—The following is the proper method for dissolving dyestuffs: Fill the container with hot water from the storage tank; sprinkle in the dyestuff very slowly with one hand while stirring with the other, the stirring being continued until all the dyestuff is dissolved. After the solution is *complete*, cold water should be added as a safeguard, to prevent the formation of granite fibers on mixed furnishes, which often occurs when the dyestuff solution is added to the beater in a too-hot condition. The quantity of water required depends upon the individual dyestuff. The best general rule to follow is to use a minimum of 40 parts of water to each one part of basic dyestuff. The solubility of some basic dyestuffs is increased by the use of acetic acid, in which case, the best results are obtained by mixing an equal weight of the acid with the basic dyestuff and adding the hot water to the mixture, with constant stirring. Hard water has the property of precipitating all basic dyestuffs and certain direct dyestuffs. Whenever it is necessary to use hard water for dissolving dyestuffs, a small amount of acetic acid should be added to the dissolving water, to compensate for the temporary hardness.

79. Solution Storage Tanks.—In mills where a single grade of paper is run continuously, such as newsprint, it is advantageous to have large mixing and storage tanks for the dyestuff solutions. The best type for this purpose is a cylindrical wooden tank containing a paddle agitator, the size depending on the production of the mill. When storage tanks are used, solutions of basic

dyestuffs should never be made up more than 24 hours in advance; for, after a period of time, the strength of the dyestuff increases. However, acid and direct dyestuffs can be stored in such tanks for several days.

80. Beater-Room Equipment.—In addition to that previously mentioned, the equipment necessary for efficient beater coloring includes a small truck, hand mold, hot plate, sieve or strainer, and various volumetric measures, such as pint, quart, and two-quart dippers.

The container that is used for dissolving the dyestuff can be kept on the truck, for conveying the color from the color room to the different beaters. A small hand mold, from 2 to 3 inches in diameter, is used to make hand samples of the stock from the beaters while the initial formula is being built up. If a hot-plate (electric or steam) be used to dry out such samples, the time that would otherwise be lost in running back and forth to and from the machine room to dry the samples on the paper machine is saved; also, in some cases, such as starting up Monday morning, the dryers may not be hot enough to dry the samples satisfactorily, and further time is lost. The initial small cost of the hot-plate will be more than compensated for by the satisfactory service obtained from it.

DETAILS OF COLORING PROCESS

ACTION OF DYESTUFFS

81. Why Shades Vary.—The shade produced by a dyestuff on different stocks varies between wide limits. With basic colors, stock containing a certain percentage of tannin-like or lignaceous material will be colored a much deeper and duller shade than stocks that have been partly or wholly bleached, since the bleaching process removes this material. For example, stocks such as unbleached wood pulps, jute, etc. contain sufficient lignaceous material to combine with all the dyestuff, leaving the back waters perfectly clear. Likewise, pulps obtained from different cooks in the same mill will often vary between 25% limits in the amount of dyestuff required to produce a given shade. In other words, a very hard or raw cook requires less dyestuff to produce a given shade than a soft cook does. Although

groundwood contains a higher percentage of lignaceous material than unbleached sulphite, the lignaceous material in groundwood is not in an as actively combinable state as in unbleached sulphite; it is for this reason that a granite effect or hairy fibers are produced in mixed furnishes that contain unbleached sulphite and ground wood.

82. Action of Basic Dyestuffs on Rag Stock.—Rag stock has very little affinity for basic dyestuffs. When using basic dyestuffs on such stock, a certain proportion of the dyestuff combines with the fibers, and a certain additional amount is held on the fibers by the size and alum; but the back waters can never be cleared up.

83. Action of Acid Dyestuffs.—Since acid dyestuffs have no direct affinity for any type of cellulose fibers, being mordanted to the fibers by the use of size and alum, they can be used on all types of stock with equal success, and will give the most even dyeings on mixed furnishes.

84. Action of Direct Dyestuffs.—As before stated, direct (or substantive) dyestuffs are named from the fact that they have a direct affinity for cellulose fibers. The greater the degree of purity of the fiber the greater is its combining power with direct dyestuffs; for which reason, they color most efficiently the bleached rag and wood pulps. Owing to the fact that the cellulose fiber in groundwood is surrounded by other material, the direct dyestuffs have little affinity for this type of stock; and, in some cases, where the groundwood is coarse, they leave uncolored shives in the paper.

MORDANTS

85. Use of Mordants.—A mordant combines with a dyestuff on or within the fiber, to form an insoluble compound; in other words, it fixes the dye. The paper industry does not use mordants to as great an extent as the textile and other dye-consuming industries, because no material that will interfere with the *sizing* of the sheet may be added in the manufacture of paper. The size and alum act as a mordant for certain dyestuffs, the degree of mordanting depending on the kind of pulp, method of beating, and the properties of the dyestuff.

86. Coloring Unsized Papers.—Because of the affinity of direct dyestuffs for cellulose fibers, they can be used satisfactorily on unsized paper, such as blotting papers. For heavy shades, however, the addition of 40 or 50 pounds of salt to the beater gives a greater depth of shade and clearer back waters. The action of salt in this case, however, is not that of a mordant—it acts as a "salting out" agent.

In a beater containing cellulose fibers, together with a certain amount of water holding a dyestuff in solution, if a more soluble salt be added to the beater, it will tend to drive a less soluble salt of the same base out of solution. The addition of salt tends to throw the dyestuff out of solution; but, on account of the affinity of the cellulose fibers for this dyestuff, the dyestuff is forced onto the fibers, instead of being crystallized out of the solution. Most dyeings with direct colors are brighter on unsized than on sized papers, because the sodium salt of the dyestuff is much brighter than the aluminum salt that is formed when alum is added to the beaters.

87. Action of Size and Alum.—Acid colors are mordanted to the fibers, in all cases, by the use of size and alum. While the presence of an excess of alum increases the retention of the color on the fibers, better results can be obtained by increasing both size and alum in proper proportions rather than by having an excess of alum only. The fact that heavier sizing increases the shade produced by acid dyestuffs, warrants the assumption that the greater the quantity of size the larger the number of particles there are to which the color may become attached, or by which it may become trapped in the fibers. Pigment colors behave in a manner similar to acid colors in this respect, far better results being obtained on the heavier sized than on the lightly sized papers.

88. Action of Soda Ash, Borax, and Other Chemicals.— When soda ash is used with certain direct dyestuffs, such as the various brands of purpurines and Congo reds, or borax is used with such acid dyestuffs as metanil yellow, it does not act as a mordant; it here serves to neutralize any excess of alum that has been added to size the paper, in cases where alum has a deleterious effect on the shade of the dyestuff.

89. To a limited degree, other chemicals are used as mordants for specific dyestuffs. When certain direct colors are treated

with copper sulphate, their fastness to light is greatly increased; two parts of copper sulphate should be used for every one part of such direct dyestuffs. Lead acetate decidedly improves the brightness and fastness of such phthalic anhydride dyestuffs as eosine, phloxine, and erythrosine.

90. The use of tannic acid, or other tannin-like materials, decidedly mordants basic dyestuffs to the various fibers. The reason their use has not been more completely developed in the paper industry is because iron has the property of darkening tannin; hence, trouble is experienced on account of this darkening action, and the paper is streaked where it comes into contact with iron.

91. After-Treatment with a Mordant.—There is no doubt but that after-treatment of the colored stock with the proper mordant would, in many cases, improve the fastness to light, two-sidedness (see Art. **106**), and would clear up the back waters. A large amount of work is still to be done in connection with this subject before a comprehensive knowledge of proper methods for coloring paper is obtained.

ORDER OF FURNISH

92. Relation of Coloring to Furnish.—The order of furnish was discussed in the Sections on *Beating and Refining* and in *Loading and Engine Sizing* but it is well again to consider it here in connection with the subject of coloring, because it bears an important relation to this subject. It must be borne in mind, however, that the methods employed for coloring paper are necessarily subordinate to those employed to obtain the maximum production of paper of the quality desired, using the equipment at hand. This accounts for the fact that, in many mills, efficient coloring methods are sacrificed for quantity production. A thorough understanding of all the factors affecting production will be of assistance in working out methods that will give the most satisfactory results under existing mill conditions.

93. Opinions Regarding Order of Furnish.—Opinions differ as to the proper order of addition (furnish) of stocks, dyestuffs, size, alum, fillers, etc. to the beater; this is natural, because of the varying water and stock conditions at different mills. In cheaper grades of paper, differences in the quality of the sheet that arise

from failure to follow the best methods of furnishing are less noticeable than in the higher grades, which are subjected to more rigid tests, both as regards their physical properties and their appearance. This matter will here be first discussed on the assumption that the stock furnished is of one type.

94. Stock All of One Type.—With soft water, basic dyestuffs should be added *before* the size and alum. If the water is comparatively hard, the dyestuff should be added *after* the size and alum; or, a small quantity of the alum, sufficient to neutralize the hardness, should be added before the dyestuff, followed by the size and the remainder of the alum.

With acid dyestuffs, the order depends upon the amount of excess alum used in the paper; if only sufficient alum be used to precipitate the size, then no difference will be perceived between adding the dyestuff before or after the size and alum; but, if an excess of alum be used in the beater, better results will be obtained by adding the dyestuff after the size and alum.

Direct dyestuffs should always be added to the beater before the size and alum; because, on account of having a direct affinity for cellulose fibers, the direct dyestuff should be allowed to come into contact with the fiber before it is coated with size and alum.

Where color formulas are built up that contain basic and either acid or direct dyestuffs, the acid or direct dyestuffs should be added to the beater and thoroughly mixed with the stock before the addition of the basic color solution. Where both acid and direct colors are used, they can be dissolved together; but if they are dissolved separately, the solution of direct dyestuffs should be added before that of the acid dyestuffs.

95. A General Rule.—A general rule for the addition of all chemicals, such as copper sulphate, lead acetate, etc., is to add them directly after the dyestuff and before the size and alum; salt should also be added immediately after the dyestuff. But, when soda ash is used, it is an open question as to whether or not it should be added before or after the size and alum. (The authors, personally, do not believe in the use of soda ash, for the good it does is more than offset by its deleterious effects.) When soda ash is added after the size and alum, it tends to dissociate the aluminum resinate, and, at the same time, to replace the aluminum radical in the dyestuff with the sodium radical. Continued beating tends to increase these two reactions, with the

result that the degree of sizing and the comparative brightness in shade will depend upon the length of time of beating.

96. Mixed Furnishes.—When mixed furnishes are used, very careful attention must be paid to the order and method of adding the dyestuffs, to prevent mottling. With basic colors on a mixed furnish of groundwood and unbleached sulphite, the groundwood should always be furnished to the beater first, followed by a cold solution of dyestuff, unbleached sulphite, size, and alum, in the order here given. On mixed furnishes containing wood pulp and rag stock, direct colors, when used, should always be added to the beater in a cold dilute solution. On account of the nature of the fiber, rag stock is always furnished to the beater before the wood pulp; consequently, it is out of the question to consider reversing this order, for the sake of obtaining a more efficient color practice at a decided sacrifice of beater practice. In order to prevent mottling on such mixed furnishes containing rag stock, where direct dyestuffs are used, it is sometimes recommended that these dyestuffs be added to the beater in a dry state as soon as the beater is furnished.

97. Adding Dyestuffs in Dry State.—In many cases, mill practice has designated that the dyestuffs be added to the beater in a dry state; but such practice is bound to result in a slight increase in the dirt content of the paper. Although the dyestuffs of reputable manufacturers are very clean, it is impossible, in the case of any commodity that must be ground and packed, to keep a very small amount of insoluble matter from becoming mixed with the dyestuff. In the cheaper grades of paper, the amount of dirt or dust from the dyestuff will be inappreciable, as compared with the actual dirt in the pulp; but, in the higher grade rag papers, this small amount may be perceptible at times. For the above reasons, the best general mill rule is to dissolve and strain all dyestuffs.

98. An Important Point.—The most important point to remember in connection with the whole subject of order of furnish is that, once a furnish and formula have become established, every beater making that order must be handled in exactly the same manner.

99. Influence of Density.—The density of the stock in the beater, which varies between 2.5% and 8% (depending on the nature of the stock and the type of the beater), has a very

decided effect on the coloring power of certain dyestuffs. As a general rule, the greater the density of the stock in the beater the greater the depth of shade obtained with a given quantity of dyestuff. This is explained by the fact that thorough brushing out of the fibers has a tendency to work the dyestuff into the fibers of all stocks that have a direct affinity for the dyestuff. In the case of acid dyestuffs, the mordanting action of the size and alum on the dyestuff is proportionately increased with the density.

COLOR FORMULAS

100. Building Up Color Formulas.—Every beater engineer has his own individual ideas concerning the best methods for building up color formulas; this is due to the fact that conditions in each mill are different, both in regard to equipment and to furnish. Before deciding upon any definite plan of procedure, the beater engineer must have a real appreciation of the many variables that influence the shade before the pulp comes off the machine as colored paper. The factors that must be taken into consideration are: the consistency (or density) of the stock in the beater, method of beating, type of dyestuff used, the effect of chemicals present, action of colored stock in chests, loss in backwater, color taken up by felts, action of heat of dryers, and finish of the paper.

101. Factors to be Considered.—When the order first goes into the mill to make a certain grade and shade of paper, the superintendent or beater engineer compares the shade with that of samples from previous runs. If a run has been made that closely approximates this shade, he can start coloring his beater with a formula approximately 20% less than the one used on his previous run. Consideration must be given at this point to the matter of amount and shade of broke that may be included in the furnish. On re-pulping broke in the beater, it loses a part of its color strength, the amount lost depending on the class of dyestuff or pigment used in coloring it. Colored broke should be distributed to all the beaters, not all dumped into one. Allowance must be made for the percentage of broke in the furnish and the proportion of coloring strength retained. Precaution should always be taken to see that too much dyestuff be not added at the start; it is far easier to add color to the beater than it is to correct for shade when the strength is too high. The dyestuff, whether in

the form of dry powder or in water solution, should not all be dumped in at one spot in the beater, but should be allowed to flow in gradually during one complete revolution of the stock in the beater, thus giving the color a more even distribution.

102. Use of Laboratory Matches.—In case the beater engineer has no guide to follow from previous runs, he must depend upon his laboratory match to approximate the initial amount of dyestuff he should add to the beater. In case the mill be not equipped with laboratory apparatus for matching shades, a sample should previously have been sent to the laboratory of one of the dye-stuff manufacturers, to obtain an approximate formula. It is much better to work from a formula with individual colors in the mill than to have a sample matched by a color house and a mixture of dyestuffs sent to the mill. In the first instance if there is any variation in the stock, water, or chemicals, this difference can be more easily overcome by the use of one or more of the component colors; whereas if the mixture is used, the shade can be varied in depth only. As stated in Art. **71,** all laboratory matches are approximations; they serve their purpose by acting as guides in building up formulas in the mill. These laboratory matches should be cut approximately 25% (Art. **70**), and then built up with one dyestuff or another, in order to obtain the correct shade.

Some color men, however, prefer to get their main shade by using a mixed dyestuff, and to give this any final variation necessary to compensate for the factors mentioned by adding more of one or the other of the component dyestuffs.

103. Matching Shades in the Beater.—After the pulps, color, size and alum have been beaten for a certain length of time, the shade of the stock in the beater should be compared with a small wet portion of the sample to be matched. Also, a hand sample, as previously explained, should be taken from the beater and dried, and compared with the sample to be matched. Only continued practice in the matching of shades in the beater will give the beater engineer a knowledge of just how a shade that has been brought up to a certain point in the beater will work on the paper machine.

That the first few pounds of paper coming over the machine may be of the same shade as that later in the run, it is sometimes necessary to color up the white water, and also to add a small

amount of dyestuff to the fan pump, to compensate for the color built up in the return waters later in the run, and for the color absorbed by the felts. This method should never be relied on unless the beater engineer has had considerable experience in making such additions; a limited experience may cause far more trouble than the good to be derived.

104. Doctoring the Shade.—As soon as the sheet that is representative of the stock in the chests comes over the paper machine, a comparison with the sample to be matched will show whether the shade is correct or whether certain additions will have to be made. There are two methods of making these additions: first, coloring the chest; second, adding an extra amount of dyestuff to the second beater to compensate for the shortage of dyestuff in the first one dropped. Coloring the chest is a difficult process to regulate; it should be avoided whenever possible, because such coloring has a tendency to make the shade run uneven. However, if this procedure be necessary, the amount of stock in the chests is estimated, the requisite amount of dyestuff is dissolved in a very dilute solution, and this solution is slowly added, either in the head box of the Jordan or directly into the chest.

The second method, that of dropping a beater with sufficient dyestuff to compensate for the difference in shade of the first beater, is very satisfactory, provided there is proper agitation in the stuff chests. In any mill making colored papers, it is absolutely necessary to have good agitation in the chests; otherwise, more harm than good is done by trying to regulate the shade by coloring the chest or by dropping the second beater. Further changes should not be made too rapidly after color or additional stock has been added to the chest, because from 15 to 30 minutes is necessary to obtain the true value of these changes over the average paper machine.

The second beater on the floor, before the paper first comes over the machine, should always contain a little less dyestuff than the first beater; for, in case the shade may come a little too heavy, the second beater can be dropped, which will compensate for the increase in shade for the first paper over the machine as compared with the sample submitted. After the shade is once established on the machine, samples of the finished paper should be compared at frequent intervals, particularly, if there be any change with respect to the basis weight or finish of the paper, or

in the amount of suction on either the suction roll or boxes; and the wet stock of each beater on the floor should be matched against the stock in the stuff chests.

105. Taking Samples from the Paper Machine.—Insofar as the writer's information goes, the taking of samples from the paper machine for the purpose of comparing the uniformity of the run in regard to color, has not, up to the present time, been done as well as it might have been. The uniformity of a color run is most effectively observed in the finishing room of the mill, where the whole run is at hand. To imitate this condition in the beater room while making the paper, two methods may be used:

(*a*) A board may be attached to the wall, on which is a row of nails. With this may be used a flat piece of tin, of trapezoidal shape, for cutting out samples of paper, the samples being cut out with this tin as they are taken from the machine. Order number, date, and serial number (as 1, 2, 3, and 4) or reel number may be attached to each sample as it is taken; and the samples are hung up on the board on the wall in the same sequence as they were taken from the machine.

(*b*) A second method, similar to the preceding, is to use a tin plate of rectangular shape, measuring about 3 by 8 inches, for cutting out samples as taken from the machine. As before, the samples are marked with the order number, date, and serial or reel number; but, instead of hanging them on a board, they are kept in a loose-leaf folder.

By either method, the samples may be kept indefinitely; and any irregularities that occur during the run of the paper may be noted on the samples, as well as their cause. This will serve as an explanation, if such be asked for after a long interval, when the details of the run may have been forgotten or recollection may be hazy. The samples are also useful in the finishing room, as they enable the boss finisher to see at a glance whether all rolls can be cut together; or, if a non-uniformity exists, he may select from these samples the rolls that are to be cut together on the cutter.

106. Two-Sidedness.—One of the most important problems in the present day manufacture of paper is the matter of **two-sidedness,** by which is meant difference in shade or texture between the top and bottom of the sheet. The degree of two-sidedness depends on the type of couch roll used, the number of suction boxes, the freeness of the stock, the amount of water

carried and the selection of the dyestuffs. A limited amount of two-sidedness is absolutely unavoidable on machines where a suction couch roll is employed. This trouble is caused by the fact that a certain proportion of the dyestuff used to obtain any shade is merely mechanically fixed, either to the fiber itself or, as in the case of acid dyestuffs, to the size and alum; hence, as the paper is formed on the wire and passed over the suction boxes and suction roll, a certain amount of this mechanically fixed color will be drawn from the bottom side of the sheet. Less trouble in this respect will be experienced with a free stock than with a slow stock.

In considering this problem, it is obvious that the extent to which two-sidedness can be minimized depends on the selection of dyestuffs that will have the greatest degree of adherence to the fibers. The degrees of affinity of different classes of dyestuffs for different stocks has already been discussed. On unbleached pulps, with basic colors, very little trouble is experienced with two-sidedness, because of the direct affinity of the basic dyestuffs themselves for the lignaceous material in the unbleached pulps. On bleached wood pulps and rag stocks, direct colors will give a minimum of two-sidedness, because these colors combine directly with the fiber.

107. Combinations of Dyestuffs.—When selecting combinations of dyestuffs for any given shade, those should be selected which have the same degree of affinity for the various stocks that are used in the furnish, in order to prevent different shades of color on the two sides of the sheet. Because of the fact that pigment colors are mechanically fixed within the sheet, the two-sidedness obtained by the use of pigments is far greater than that obtained with the aniline dyestuffs. An exception is in the use of certain pigments made from aniline dyestuffs, which, due to admixture with certain chemicals in their process of manufacture, more or less mordant such colors to the paper fibers; hence, they have less two-sidedness than many of the aniline dyestuffs themselves. By proper methods of sizing, in other words, by the thorough admixture of the size with the stock before the addition of alum (preferably added in a dilute solution), the two-sided effect will be greatly decreased.

108. Effect of Heat.—No general rules apply to the effect of heat on the various groups of dyestuffs. As before stated, in

connection with the dissolving of dyestuffs, Art. **11,** no basic colors should ever be heated to the boiling point. In certain cases, for example, auramine and basic or Bismark browns, a temperature limit of 160°F. for the dissolving water should be adhered to. After the dyestuff has been placed in the beater, no trouble will be experienced from the effect of heat on any color, provided the temperature is not raised above the point that will affect the sizing. On the paper machine, certain dyestuffs have the property of changing in shade, due to the heat of the dryers. The manner in which they change is entirely individual with different dyestuffs. Chrysoidines and basic browns in sized papers have a tendency to be redder when they first come off the machine than they are after the paper has assumed a temperature and moisture content conforming to atmospheric conditions. Certain acid colors have a tendency to burn on the surface of the sheet. In some cases, if the dryers are too hot, this burning will be very spotted, and it will practically spoil the sheet. Dyestuffs that have a tendency to spot should be avoided.

With acid dyestuffs, in many cases, the color itself is very much stronger on the surface than in the middle of the sheet; this is not a disadvantage, except in very heavy papers, such as cover papers. In cases of direct colors, the increase or difference in shade caused by the heat of the dryers is lost as soon as the paper is in equilibrium with atmospheric conditions. For this reason, when matching shades with direct colors, it is a good policy to take a sample taken from the machine and wave it in the air for 4 or 5 minutes, (to cool it) before comparing with the sample to be matched.

109. Effect of Finish.—The degree and type of finish given the paper has a decided effect on the depth of shade obtained with a given quantity of dyestuff. The more highly calendered the sheet the greater will be the depth of shade; in other words, with a given quantity of dyestuff, a supercalendered sheet will have the appearance of being much more heavily dyed than a machine-finished sheet. Water-finished papers have the appearance of greatest depth, as compared with any other type of finish. As stated before, when matching the highly finished sheets, it is necessary to steam them before comparing with unfinished samples coming off the machine. For color comparison, samples should be taken, whenever possible, from the run, before the paper goes through the calenders.

110. Beater-Room Practice.—The general rules that must be followed to obtain efficient beater-room practice vary with different mills, on account of the existing conditions as to equipment and materials. From what has been previously stated, a general idea of efficient operation, as applied to each particular manufacturer, may be obtained. Attention is called to the following points because of their application to any situation:

All vessels in which dyestuffs are dissolved should be thoroughly cleaned as soon as they have been used. Except in certain special cases, dyestuffs should always be dissolved at temperatures just below the boiling point of water, and they should be strained before adding to the beater. During the process of packing, as well as when opening kegs or barrels at the mill, small quantities of dirt and insoluble matter are liable to become mixed with the dyestuff; hence, it is a good general rule always to strain the dyestuff solution. Strainers should be kept scrupulously clean and should be inspected frequently for any damage.

When once a formula has been adopted, it is most essential that the order of addition of different dyestuffs, size, alum, fillers, etc. be strictly adhered to. Samples of all runs, with formulas attached, should be kept by the beater engineer; and, on each sample, all notations regarding speed of machine, basis weight, conditions of stock, etc. should be tabulated, so that in case another run is made that requires changing the formula, an explanation may be obtained as to the cause of such change.

CALENDER AND OTHER METHODS OF COLORING

111. Calender Coloring.—Calender coloring comes next in importance to coloring in the beaters. This process resembles staining rather than actual dyeing; in fact, it is virtually a water finish, in which a color solution is used instead of water only. In calender coloring, the dyestuff solution is allowed to flow constantly into one or more water or color boxes on the calenders, this solution being picked up through the rapidly revolving calender rolls and applied to the surface of the paper as it passes between these rolls.

112. Low Cost.—The principal advantage of calender coloring is its low cost. Acid dyestuffs are most commonly used for

this purpose because of their generally good solubility, and because, having no direct affinity for cellulose fibers, the shade produced runs more uniform than with any other class of dyestuffs. Acid dyestuffs are also more stable to continued temperatures up to the boiling point, which sometimes makes their use advantageous in this type of coloring.

113. Calender Coloring with Basic and Direct Dyestuffs.— Basic dyestuffs are sometimes used in calender coloring in those cases where extreme brightness and minimum cost are more important than uniformity of shade. The basic dyestuffs have a tendency to mottle and streak the finished paper, and to deteriorate in strength upon standing in the hot solution. The direct colors are also used occasionally for calender coloring; but these also have a tendency to streak the paper, and they have neither the advantage of cost nor brightness over the acid dyestuffs.

114. Apparatus Employed.—The apparatus for calender coloring consists of: a tank, or barrel, for dissolving the dyestuff, into which runs the overflow from the water boxes; a solution storage tank, which is set on a platform at a height above the top of the calender stack, from which the pipe to the water boxes is led; a circulating pump, for the purpose of transferring the solution from the dissolving or overflow tank to the storage tank. The strength of the dyestuff solution is determined by the shade required. In cases where the shades are produced by combinations of dyestuffs, concentrated solutions of the individual dyestuffs should be made up and mixed together in the dissolving tank until the proper shade is obtained; they should then be diluted to the proper strength, either in the dissolving tank or in the storage tank. The water boxes are made with one side, two ends and a bottom. The ends are shaped to fit closely the calender roll against which they fit, and leakage is prevented by rubber packing at the ends and a rubber lip on the edge of the bottom. The box is set against the upward turning side of the roll.

115. Formulas for Calender Coloring.—The following procedure is recommended for working out calender-coloring formulas before the actual run is started. A time is selected when the paper going over the machine approximates the furnish of the paper to be colored. The water box is dammed back several

inches from the edge of the sheet, and the color solution, which is being made up in the dissolving tank, is poured onto the face of the calender roll, where the sheet is running dry. This gives the same effect as will be obtained when the color solution is used in the water boxes; consequently, by changing the strength of the solution and the relative proportions of dyestuff in the dissolving tank, the proper formula can be worked out.

As soon as the run is started, the color solution flows from the storage tank into the water boxes, on either or both sides of the sheet, in the same manner as water is applied for the regular water finish. When only one side of the paper is to be colored, water must be run into the water boxes on the opposite side of the sheet, in order to get an even finish and to counteract curling.

116. Efficiency of Calender Coloring.—The degree of efficiency of calender coloring depends largely upon the manipulation of the paper before it reaches the calenders. The degree of sizing also has a decided effect on the results obtained. If the paper is slack sized, the dyestuff solution will penetrate deeply through the surface, giving a greater depth of shade than is the case with a hard-sized sheet; it will also make the paper feel damp, and it will be without snap. With a light or medium-sized paper, only one color box is necessary; but, with a hard-sized sheet, it is sometimes necessary to run two color boxes, in order that the second box may cover up the light spots from the first color box, and thus give a uniform shade. The degree of penetration of the color solution increases with the temperature of the solution and the heat of the calender stack; hence, in order to obtain uniform results, these two factors must be kept constant. A well-formed sheet will also dye more evenly than a wild sheet, because calender coloring accentuates any irregularities in the paper itself. Where trouble is experienced because of streaking on the calenders, the addition of a small amount of soap in the dyestuff solution will usually eliminate this difficulty.

117. Combination Method.—A combination method, whereby the coloring is done partly in the beater and partly on the calender, is often used. The relative proportion of the two methods thus employed depends upon the cost and the results desired. The principal use of calender coloring is on different grades of box boards and container boards, and a great variety of economical shades may be produced on this type of stock.

Through this method of coloring, different shades on opposite sides of the paper or board can be produced by having the water boxes on opposite sides of the calender stack filled with different dyestuff solutions.   Just sufficient solution is taken up by the sheet to give it a good finish on the calender stack.   Sometimes steam is used in hollow calender rolls.

118. Tub Coloring.—Tub coloring is used to a very limited extent.   In this process, the paper, in a semi-dry condition, is passed through a tub, situated approximately half way or two-thirds of the way to the dry end of the machine; and after passing through this bath, and then through squeeze rolls, it is dried. There are no distinct advantages to this type of coloring; it is used only in special cases, where a slight saving in cost over beater coloring can be made, and when greater penetration can be obtained at the same time than by calender coloring.

119. Oatmeal Papers.—Oatmeal papers are used practically exclusively for wall papers, and the oatmeal effect may be obtained by washing a suspension of *wood flour* over the surface of the sheet on the wire.   In a majority of cases, the paper itself is highly colored, while the wood flour is in its natural state of color.   In some cases, however, the body of the paper is white, while the wood flour is colored in various hues.   In some isolated cases, ordinary groundwood is used in place of the flour, but this has never proved satisfactory, on account of being too coarse. Dyestuffs used for this purpose should have the properties of being fairly fast to light, and of resistance to the alkali that is in the paste used for hanging these papers; and must have the property of not bleeding, in order to prevent the wood flour from absorbing the dyestuff in the paper.   On account of the requirements just mentioned, direct dyestuffs are generally used for this type of work; but, by careful attention to their method of application, certain acid and basic colors are used very efficiently. Another method is to mix the stock in separate chests and bring them together in a specially prepared head box on the machine.

120. Mottled or Granite Papers.—Granite or mottled papers are made by adding a small percentage of highly colored fibers to the furnish.   The amount of these colored fibers ranges from $\frac{1}{4}\%$ to 3%, depending on the intensity of the granite effect desired.   The colored fibers are usually made by dyeing either rag or unbleached sulphite with direct colors.   The colored

fibers are prepared by coloring a beater of stock, in the regular manner, with direct colors, adding 40 to 50 pounds of salt per 1000 pounds of stock, heating to 140°F., cooling to below 100°F., adding a small amount of size and alum, and then subsequently running the stock into laps on a wet machine. During this last procedure, any color that is only mechanically fixed to the fiber will be washed out; hence, the pulp in the laps will not bleed when it is mixed with the white or natural stock, in the production of the granite papers.

Very good effects in granite papers are obtained by adding to the white stock two or three different shades of pulp that have been colored in this manner. Where the granite fibers are black in color, black stockings are often used. Varied effects can also be obtained by using wool, jute or various long grass fibers in place of rag or unbleached sulphite.

121. Blotting Papers.—The type of color used for blotting papers depends upon the grade or furnish of the paper. In the better grades of blotting paper, manufactured from a large percentage of rag stock and sometimes containing a small amount of soda pulp or unbleached sulphite, direct dyestuffs should be used exclusively. In the very cheap grades of blotting paper containing unbleached sulphite, soda, and groundwood, basic colors are as suitable as direct dyestuffs.

Direct dyestuffs can be more efficiently dyed on the fiber by the addition of 30 to 50 pounds of salt per 1000 pounds of stock, and raising the temperature to 140°F. The addition of a minimum of 10 pounds of soda ash tends to brighten the shade of the direct dyestuffs, and it has no injurious effect on the paper. The objection to the use of soda ash mentioned previously does not apply here, as the paper is not sized. In order more firmly to fix the dyestuff on the fiber, it is the practice of some mills to add a small amount of alum to the beater; but this practice should be discouraged for two reasons: First, any quantity of alum over $\frac{1}{2}\%$ to 1% has the property of destroying the blotting qualities of the paper; second, as stated in Art. **13,** alum deadens the shade of direct dyestuffs, and, in the presence of the heat of the dryers, it often tends to vary the shade sufficiently to make uniform results difficult to obtain. On the cheaper grades of blotting paper containing groundwood, the addition of a small quantity of alum aids materially in the retention and uniformity. Because of the fact that they have no direct affinity for any fibers

and require a mordant, acid colors should never be used for this type of work.

122. Duplex Papers.—Duplex papers can be made at the calenders of a Fourdrinier machine by coloring one side of the calender. In the case of two-ply or multiple-ply sheets made on a cylinder machine, either the top or bottom liner or both can be colored. Duplex sheets can also be made on a Fourdrinier or Harper machine by having a vat and cylinder mold attached to the paper machine, and having the paper from this cylinder mold carried by a felt, so as to meet the paper from the machine wire just after passing through the couch rolls, where the two papers are pressed together into the duplex sheet, as described more fully in Section 1, Vol. V.

123. Spray Dyeing.—Spray dyeing is a relatively new process; and it is only within the last few years, that it has developed to considerable commercial importance. Its advantage lies in the fact that very beautifully colored papers can be produced at a low cost, with a minimum consumption of dyestuff.

Spray dyeing may be divided into two types: In the first type, a dyestuff solution is sprayed onto the sheet of paper by means of a spray nozzle, using air under high pressure to force the color solution through fine orifices; and so arranged that it will strike the paper either before or after passing over the first suction box, depending on the effect desired. In the second type, the dyestuff is spattered on the sheet from rotating brushes, which travel through the dye bath and then against a baffle plate, which draws back the hairs of the brushes; and when they pass the baffle and return to their original position, the color is thrown on the sheet. Direct dyestuffs are more suitable for this work.

124. Cloudy Effects.—There are numerous methods for obtaining cloudy effects, either by washing undyed pulp onto a colored stock as it passes over the machine wire or by coloring the pulp and washing it onto a white sheet; in either case, direct dyestuffs should be used. Where the stock used is either unbleached wood pulp or groundwood, basic dyestuffs may be employed for coloring the body of the sheet.

125. Crepe Tissues.—Crepe tissues are colored by the dipping process, which is the same, in many respects, as tub coloring. This coloring is done at the same time as the creping of the paper.

The machine required consists of two steel rolls, the bottom one of which is covered with a closely woven woolen cloth or with rubber, while a doctor blade crepes the paper as it is removed from the upper steel roll, after the paper has passed between the two rolls. The lower roll is always in contact with the dyestuff solution, which is maintained at a constant level in the color box, in which this lower roll revolves. Acid colors are most suitable by far for this type of work, because of their even dyeing qualities; though for very heavy shades, where brightness is more essential than even dyeing qualities, basic colors are used. Direct dyestuffs are employed for this type of work only in rare cases, where certain fastness properties must be maintained.

One essential in the coloring of crepe tissues is to maintain a constant temperature of the dyestuff solution, in order to obtain a uniform depth of shade. In some cases, a small amount of casein is added to the dyestuff solution, as it causes the paper to adhere more securely to the upper steel roll, and gives a better creping effect.

126. Parchment Papers.—In the manufacture of parchmentized paper, the dyed paper is passed through a bath of strong sulphuric acid. Only dyestuffs that will not be affected by sulphuric acid can be used for this type of work. The tests referred to in Art. **63**, will indicate the action of each dyestuff against acids, alkalis, etc., and should be applied when making a selection of dyestuffs for this work. The most secure method is to submit each individual problem of this type of work to the laboratories of the dyestuff manufacturer.

127. Vulcanized Papers.—In the manufacture of vulcanized papers, the dyestuff used must not be affected by the zinc chloride-hydrochloric acid solution employed in vulcanizing. Certain direct dyestuffs are suitable for this work; but, as mentioned in Art. **126,** the safest way is to submit each individual problem to the laboratories of the dyestuff manufacturer.

COLORING

EXAMINATION QUESTIONS

(1) (a) Name the principal groups of coloring matters. (b) Which group is the most important, and why?

(2) What are the distinguishing characteristics of acid, basic, and direct dyestuffs?

(3) What particular values are possessed by pigments for coloring paper, considered from the standpoint of (a) cost? (b) permanence? (c) tinctorial power?

(4) How is Prussian blue formed? Would it be advisable to use it for coloring soap wrappers?

(5) Mention the principal steps in producing a dyestuff from coal.

(6) (a) What is meant by standardizing the strength of a dyestuff? (b) How is this necessary operation sometimes abused?

(7) Explain in detail how to determine whether a particular color is a single dyestuff or a mixture.

(8) Describe a method for estimating the coloring power of a dyestuff.

(9) What standard solutions should be kept in the color testing laboratory, and why are they needed?

(10) (a) What classes of paper should be fast to light? (b) Is change of color always due to the dyestuff?

(11) After making laboratory test and calculation, what precaution is necessary when coloring a beaterfull of half-stuff?

(12) Mention the principal parts of an equipment for a color room in a paper mill.

(13) Explain the dissolving of a dyestuff.

(14) What factors affect the shade of a paper.

(15) Explain the action of size and alum when coloring paper.

(16) (a) Explain what you understand by mordanting; (b) why is the use of tannic acid for this purpose objectionable?

(17) When the water is hard, what precaution should be taken if a basic dye be used?

§5

(18) How does the density of the stuff in the beater affect the coloring?

(19) (*a*) what is *two sidedness*, and how is it caused? (*b*) how can it be minimized?

(20) Describe the process (*a*) of calender coloring; (*b*) of making mottled papers.

PAPER-MAKING MACHINES

(PART 1)

By J. W. Brassington

THE PAPER MACHINE AND ITS EQUIPMENT

GENERAL DESCRIPTION

1. Introductory.—The object of this Section is to explain, in so far as is possible, the best methods of handling a paper machine in order to obtain the best results, both as regards the quantity and the quality of the paper produced. It is not the aim to train paper-machine designers, but to impart to paper makers the essential knowledge regarding the construction and operation of paper machines and the auxiliary apparatus. If the paper maker finds herein real information as to causes of trouble in paper-machine operation and their remedy, and hints of how to improve working conditions, and of how to avoid trouble, the purpose of this Section will be fulfilled. The information here given has been selected from the advice imparted by, and the opinions of, practical paper makers throughout the world. It is not possible to record here all the information thus collected; hence, only the most important facts are given. The student should keep his own notebook, and should enter in it all interesting facts that come up in the course of his experience, particularly those relating to any troubles that arise, their cause, and their remedy. The mill is the student's laboratory, and his daily work a series of demonstrations and experiments. They should be recorded. Such a notebook, if carefully kept and indexed, will be of great value and assistance in his future work.

Before explaining in detail the various machines and appliances, it is advisable to trace the course of the paper through the machine; in this way, a knowledge of some of the most important features concerning the manufacture of paper will be impressed on the mind, and the relationship of the various parts to one another will be made clear. It will be of advantage to the student to give careful attention to the following article.

2. Course of Paper through Machine.—The principal parts of the modern paper machine, and the course of the paper through it, are shown diagrammatically in Fig. 1. On account of its length, the drawing has been cut in two in the middle, the right-hand part being placed below the left-hand part. Here a and b indicate the same point when the two parts are united.
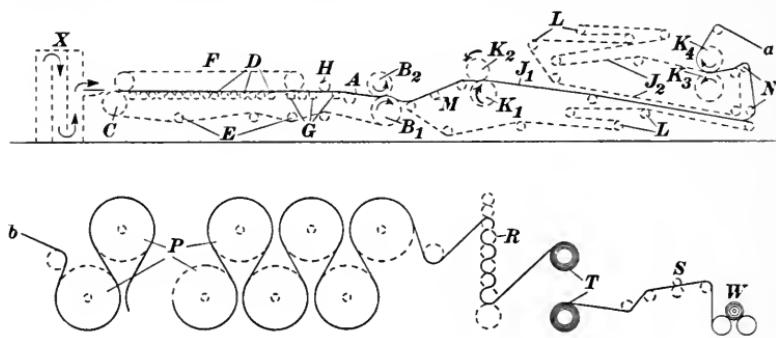
Fig. 1.

The first section (the upper, or left-hand, part) is called the **Fourdrinier part, or wet end**; this will be described first. The stock is conducted from the flow box X over an oilcloth or rubber apron to the wire screen A, which is driven by the couch roll B_1, and is supported by the breast roll C, table rolls D, and wire rolls E. The deckle straps F keep the stock from running off the edges of the wire. Much water drains through the wire at the table rolls, more water is taken out by the suction boxes G, and the fibers are laid down by the dandy roll H (sometimes omitted) and the couch roll B_2. If a suction couch roll be used, air pressure is substituted for the weight of the upper roll B_2.

The second section (which follows the wet-end part) is called the **press part**. Here the sheet is carried by the felts J_1 and J_2, and passes between the press rolls K_1, K_2 and K_3, K_4 (some machines have three or four such presses), where more water is squeezed out, the sheet is further pressed and is prepared for a

smoother finish.   The felts are carried on rolls L, sometimes over a felt suction box M.   The direction of rotation of the last press is usually reversed, so as to give the paper approximately the same surface on both sides; and where the course of the paper is thus changed, the sheet is supported by paper-carrying rolls N.

From the presses, *the paper* (now containing about 60% to 70% of water), passes to the dryers P, shown in the lower part of the illustration.   These latter are steam-heated cylinders; the paper is kept in contact with their hot surfaces by cotton (or canvas) felts, and most of the water left after pressing is here evaporated.   The number and the size of the dryers varies in accordance with the weight and the grade of the paper, and with the speed of the machine.   The opposite side of the sheet is next to the iron on successive dryers, thus drying the paper more evenly and giving a more uniform finish.   The finished sheet contains from 7% to 10% of moisture.

Most papers are finished on the machine by passing through the calenders R (*calender stack*).   These constitute a set of very smooth iron rolls, which press heavily on the paper.   By reason of their weight and the friction generated when the paper passes through them, the paper is "ironed out," as it were.   This operation is called *calendering*.   The web is then wound on the reels T, of which there are several types.   When a reel is full, the paper is transferred to an empty one, and the full reel is thrown out of gear.   The paper from the full reel is slit into strips by revolving slitters and wound in rolls of the width and diameter desired.   The slitter is shown at S and the re-wound roll at W.

The several sections of the machine must be capable of adjustment to slight variations in speed in relation of one to another, and provision is also made for varying all sections in unison. There are several methods of driving the paper machine, and these will be described after the several sections just mentioned have been explained in detail.

PAPER-MACHINE ROOM

3.   Circulation of Stock.—Fig. 2 shows a paper-machine wet-end in plan and elevation.   The vertical stuff chest C receives the stock, which is continually agitated in it; and which either flows into it or is pumped into it from the beater, mixer, or beater

chest, usually passing through the Jordan engine. The stuff pump A delivers the stuff from the stuff chest C to the regulating box B, and it flows from the latter over the riffler or sand trap D to the screens F and F. In the case of stock for fine rag papers, it also passes over a magnet E before reaching the screens F. The screened stock passes through pipe G into the flow box H,
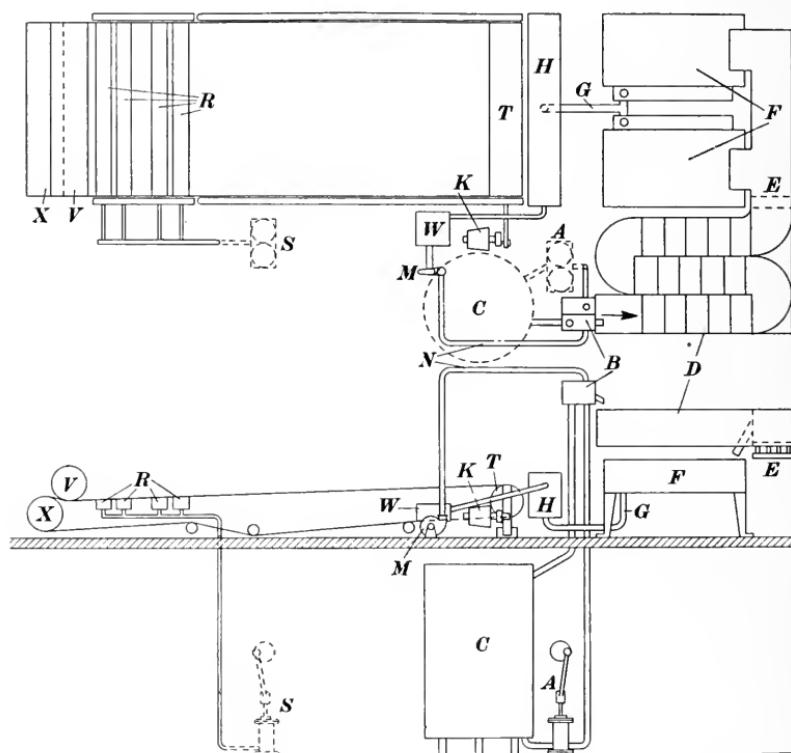
Fig. 2.

from whence it flows upon the wire. The overflow from flow box H goes to the white-water box W. The centrifugal pump M sucks what water is needed to dilute the stock from the white-water box, and discharges it through pipe N into the regulating box B. The overflow from the regulating box goes back to the stuff chest. The remainder of the white water is generally treated, in a manner to be described later, for the recovery of fiber, etc. Attention is called to the pump S, which is here shown in dotted lines because it is under the machine-

room floor and in the basement; this is the pump that maintains a vacuum on the suction boxes. The vacuum system is provided with a separator, for removing air from the water that is drawn from the paper.

It is important that the student familiarize himself with the circulation of the stock and water, using Fig. 2 and the diagram in Art. **21** as guides, and that he keep the main principles of this circulation clear in his mind.

4. Paper-Machine Room Details.—Stuff chests may be horizontal or vertical, and there may be one or two to a machine. Both stuff chests and stuff pumps are described in Section 3, *Beating and Refining*. Plunger stuff pumps may be single, double, or triple. They are always single acting. In some mills, centrifugal pumps are used. Pumps with 1, 2, or 3 plungers are called simplex, duplex and triplex respectively. The regulating box, of which there are several patented types on the market, may have two, three, or four compartments. The rifflers may be simply wooden boxes (troughs) with suitable baffles to prevent the passage of heavy particles. The screens may be flat or of the rotary type. The flow box may have two, three, or four compartments; and the overflow from the flow box may go to the beater chest instead of to the white-water box. The discharge of white water from the centrifugal pump may go to the regulating box, to the beaters, or to save-alls. Every mill presents slight differences in details from every other mill, in accordance with the ideas of the man in charge. The student, therefore, should grasp the general ideas of paper making; after which, he can design his own rifflers, regulating boxes, etc., and he can choose what circulating methods he prefers.

IMPORTANT AUXILIARY EQUIPMENT

STUFF CHESTS

5. Description of Stuff Chests.—The **stuff chest** is a large cylindrical-shaped tank, usually vertical. It may be made of iron, wood, or concrete, care being taken that the interior is smooth and that there are no corners or angles for the stuff to lodge in. Fig. 3 shows a vertical stuff chest, and Fig. 4 shows a horizontal stuff chest. The central shaft revolves at a moderate

speed, so as to keep the pulp thoroughly mixed.   The paddles make from 15 to 20 r.p.m. when making rag papers.   If the agitator paddles turn too rapidly, they tend to churn light
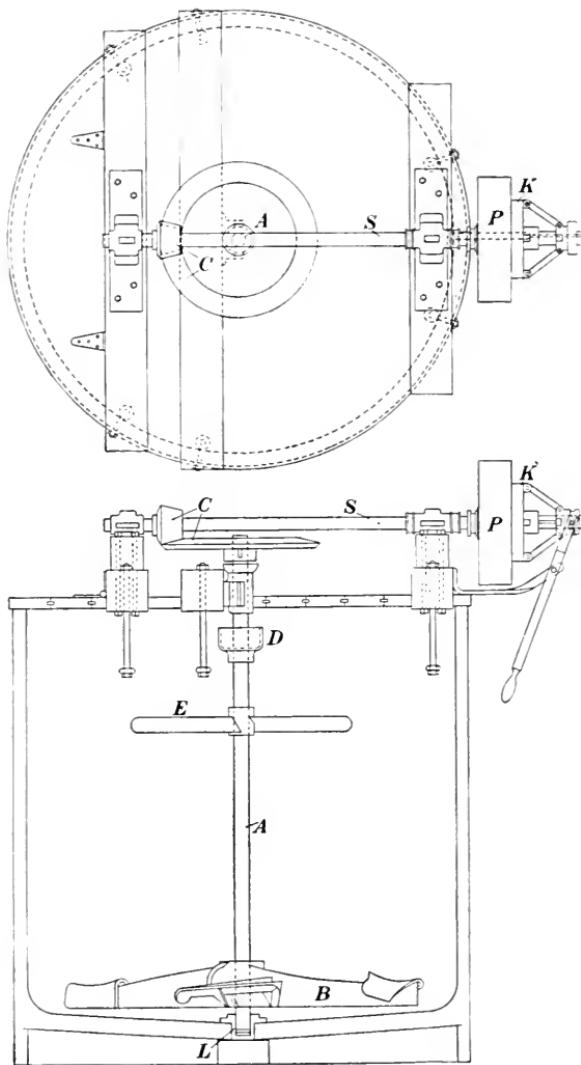
Fig. 3.

fibers into soft knots; if they turn too slowly, they cause variation in weight by allowing the heavier stock to settle.   More detailed descriptions of Figs. 3, 4, 5 and 6 will be found in Section 3.

With vertical chests, the gearing may be so located underneath them that dirt and grease cannot drop into them. When the gear is placed below the chest, a stuffing box and gland are used to prevent leakage. This type of stuffing box is used also on the end of the shaft that extends through the sides of horizontal stuff chests to the driving mechanism. A good design of stuff chest will permit thorough washing and complete emptying, so as not to waste stock.
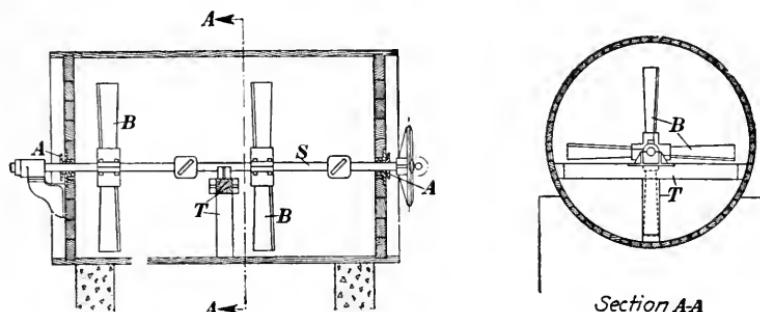
Fig. 4.

6. Capacity and Size of Stuff Chests.—Vertical stuff chests are generally about 12 feet in diameter and from 6 to 14 feet deep, according to the size of the machine. A stuff chest should hold enough (two beatersful, at least, especially of colored stock) to supply the paper machine for an hour or more, and to give plenty of time for the beaters to replace their contents. If the stuff in the chest is allowed to run low between charges from beaters or mixers, there is likely to be variation in the weight of the paper, due to pulsations in the chest. The consistency of the stuff in the chest is from $2\frac{1}{2}\%$ to 3%. The stuff in the beater is diluted by the water required to wash it down to the beater or Jordan chest—which is necessary when a Jordan is used and where colored papers are made.

The size of a stuff chest is readily calculated. For example, suppose a machine to make 12 tons of paper per day of 24 hours, and it is desired to find the size of a vertical stuff chest for this machine. The calculation would proceed as follows:

$$\text{Average amount of paper made per hour} = \frac{12 \times 2000}{24}$$

= 1000 lb. The beaters hold, say 1200 lb. of paper pulp; and since the capacity of the stuff chest must be at least 2 beatersful, it must hold $1200 \times 2 = 2400$ lb. of paper. Assuming that the

consistency of the stuff is 2.4%, the weight of the stuff in the chest is 2400 ÷ 0.024 = 100,000 lb., a cubic foot of which weighs from 62.5 to 63.0 lb.   Assuming that it weighs $62.5 = \dfrac{1000}{16}$ lb., the volume of the chest is $100,000 \div \dfrac{1000}{16} = 100,000 \times \dfrac{16}{1000}$ = 1600 cu. ft.   If the inside diameter of the chest be taken as 12 ft., the area is $12^2 \times 0.7854 = 113.1-$ sq. ft.; consequently, the depth of the chest is 1600 ÷ 113.1 = 14.15 ft., say $14\frac{1}{2}$ ft.

7. Care of Stuff Chests.—The stuff chests should be well cleaned whenever there is an opportunity during periods that the mill is shut down; and, particularly, this must always be done when the kind of paper being made is changed.   Wooden stuff chests that are not in use should be kept full of water, being freshly filled at intervals of, say, three or four weeks; this keeps the wooden staves water soaked, and it prevents leaks and deformation.   The iron straps should be painted periodically, to keep them from rusting.   Agitation of the contents of a stuff chest is very important; it can be assisted by allowing the centrifugal pump that takes from the Jordan chest to discharge tangentially into the stuff chest, thus causing the stock to tend to flow along the outer wall of the chest.   This method is only applicable to very light papers, such as newsprint or cheap magazine papers.   A special mixing chest for newsprint paper is described in the Section on *Beating and Refining*.

8. Horizontal Stuff Chests.—As previously stated, stuff chests may be horizontal as well as vertical.   Some paper makers prefer a horizontal chest having a series of vertically acting paddles, which are so made that the stuff is forced one way along the center of the chest, and is then returned the other way, on the outside, near the shell.   This result is obtained by reversing the inclination of the paddles on the revolving arms.

In mills where colored papers are made, horizontal stuff chests are not considered to be a good installation.   When a color is poor, and the strength or brightness of the color is to be "brought up" or intensified by adding more color in the beaters, horizontal stuff chests do not produce results on the machine as quickly as vertical stuff chests; the contents of a beater do not "mix in" as quickly, when they are dumped into a horizontal stuff chest. Furthermore, the horizontal chest has the disadvantage of

spattering, when it is partly full, and of requiring stuffing boxes
for the agitator draft.

<div align="center">STUFF PUMPS</div>

9. Description of Plunger Pump.—The contents of the machine
stuff chest are pumped to the regulating box by the **stuff pump,**
which has its suction pipe connected to the bottom of the stuff
chest. Fig. 5 shows a simple stuff pump of the usual design; a
more extended description
of it is given in Section 3,
Beating and Refining.

Fig. 5 illustrates a single-
acting, single-cylinder,
plunger pump. The plunger
A is moved up and down
by the revolutions of an
eccentric. As the plunger
goes up, the ball valve *F* is
lifted, and the stuff from the
stuff chest is sucked into the
space *D* and into the pump
cylinder. When the plunger
reverses its movement and
goes down, the ball *F* drops
to its seat, closing the open-
ing, and the ball valve *E* is,
in its turn, forced off its
seat. Liquid equal in vol-
ume to the volume displaced
by the plunger during its
downward movement can-
not now find room in space
D, and it is therefore forced
to flow through the opening
left by ball *E* into the dis-
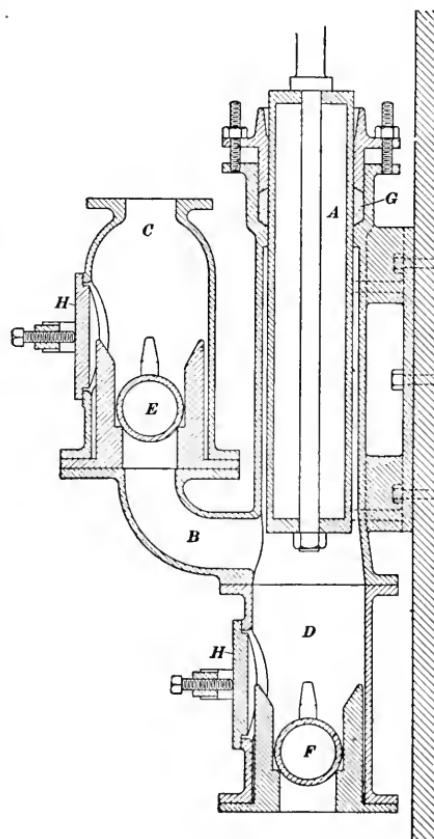
<div align="center">Fig. 5.</div>

charge pipe *C*, which delivers it to the regulating box. The
pressure forcing the liquid through the discharge pipe is that
exerted by the driving eccentric on the plunger. When the
plunger again reverses, beginning its upward stroke, the pressure of
the water in the discharge pipe (the back pressure) forces ball *E*
to its seat, and thus keeps the liquid from flowing back into the

cylinder. This type of plunger pump is largely used on machines of small size; the eccentric is keyed to a revolving shaft, which is driven by pulley and belt. Hand holes, covered by plates H, serve for replacing balls, cleaning, etc.

Double and triple plunger pumps, of the same valve and cylinder design, are used for larger machines that call for a greater stuff-pump delivery per minute. These pumps give more impulses per minute, and there is a more regular flow of liquid and less shock. Except that they are gear driven instead of eccentric driven, the general design is the same as in the pump just described. The advantage of using gears is that the belt pulley can turn faster and the belt used may be smaller, for the same power, the gears reducing the speed of the plunger to that desired.

10. Size of Pump.—It was previously stated (Art. **6**) that the average consistency of the stuff in the chest, and which is to be pumped, is about 2.5%; that is, for any given volume of stuff, approximately 2.5 parts are pulp and 97.5 parts are water, which is a ratio of $97.5 : 2.5 = 39 : 1$. In other words, there are about 40 lb. of water to 1 lb. of pulp. In some cases, this ratio may be as high as $50 : 1$, and since it is always necessary to provide for extreme cases, this last ratio will be taken in calculating the size of the pump to be used. Suppose, as in Art. **6,** that the machine is to make 12 tons of paper per day of 24 hours, or 1000 lb. per hour; this is equivalent to $1000 \div 60 = 16\frac{2}{3}$ lb. per min. The plunger of the stuff pump must therefore displace approximately $16\frac{2}{3} \times 50 = 833\frac{1}{3}$ lb. of stuff per min. Taking the weight of a cubic foot of the stuff as 62.5 lb. $= \frac{1000}{16}$ lb., the volume of the stuff delivered by the pump is $833\frac{1}{3} \div \frac{1000}{16} = 833\frac{1}{3} \times 0.016 = 13\frac{1}{3}$ cu. ft. per min. $= 13\frac{1}{3} \times 1728 = 23,040$ cu. in. per min. It is not good practice to run a stuff pump over 30 r.p.m., which, for the single-acting, simple pump just described, gives 30 working strokes per minute. Consequently, the displacement of the plunger per stroke (revolution, in this case) must be, at the very least, $23,040 \div 30 = 768$ cu. in., under the conditions assumed. Since in 1 U. S. gal. there are 231 cu. in., the plunger must displace $768 \div 231 = 3.32$ gal. per stroke. It is good practice to use large pumps, since they can be run more slowly and will last longer without repairs; hence, it would be advisable to make the displacement of this pump about 4 gal. per stroke. A cylinder 9 in. in diameter and 15 in. long holds 4.13 gal.; therefore, the

diameter of the plunger might be made 9 in. and the stroke might be made 15 in.; that is, the pump would be 9 in. × 15 in.   It would not be advisable to use a smaller cylinder, because no allowance has been made for "slip." In any case, a pump must have excess capacity, in order that a constant head be maintained on the discharge orifice of the regulating box, the overflow from the regulating box returning to the stuff chest.

11. Horsepower of Pumps.—When calculating the horsepower required to pump stuff, it is important to remember that the pressure required to pump stuff is often $2\frac{1}{2}$ times as great as that required to pump water against the same lift, because of the greater friction in the pipes.

Assuming, as in the last article, that the pump is to deliver $833\frac{1}{3}$ lb. of stuff per min., and also assuming that the total lift is 40 ft., the theoretical horsepower is $\dfrac{833\frac{1}{3} \times 40}{33,000} = 1.01$ h.p.   This result assumes an efficiency of 100%; but the actual efficiency of such a pump will not exceed about 50%, and the actual horsepower when water is pumped will be $1.01 \div 0.50 = 2.02$ h.p.   When pumping stuff, however, the resistances may be 2.5 times the resistances when pumping water, as stated in the last paragraph; consequently, the actual horsepower is $2.02 \times 2.5 = 5.05$ h.p., or, say 5 h.p.

12. The Work of the Stuff Pump.—The work required of a stuff pump in a paper mill is very severe, and is continuous.   The paper maker demands a reliable pump,—one that will always do its work faithfully under exceptionally trying conditions,—and he rightfully claims that the commercial efficiency of a fool-proof, reliable stuff pump is a vital essential part of his paper-making equipment.   The stuff pump may be considered the heart of the paper machine, and the suction pump may be called the lungs; so long as both are always working properly, the paper maker does not grudge them a comparatively large input of power.

In order to reduce the work done by a stuff pump for any given or required delivery,—thus not only reducing the power necessary to drive it but also increasing the life of the pump, by relieving it of unnecessary wear and tear,—it is always advisable to make the suction pipe of ample area and as short and direct as is possible; it should be connected to the bottom of the stuff chest, and the stuff should feed into the pump by gravity whenever

practicable. The delivery pipe should be at least as large in diameter as the discharge outlet of the pump, and as much larger as is convenient. In some mills, copper or brass pipe is used for conveying the stuff so as to minimize contamination by iron.

A more complete treatment of the subject of pumps will be found in the Section on *General Mill Equipment*, Vol. V.

THE REGULATING BOX

13. Functions of the Regulating Box.—Two important functions of the **regulating box** are: first, it regulates the *amount* of stock going to the paper machine; second, it regulates the *consistency* of the stock going to the paper machine. The amount of stock is regulated by so operating a gate or valve that just the right amount of the stock which is pumped from the machine stuff chest by the stuff pump, is delivered to the mixing compartment or mixing box. The consistency of the stock is regulated by controlling the amount of water (usually white water collected under the wire) with which the stock is diluted. The amount of actual fiber delivered by the stuff pump varies with the consistency in the chest; and the extent of the dilution must be changed in accordance with the freeness of the stock and the speed of the machine. A slow stock requires less dilution, because the water then stays longer with the fibers.

14. Uniformity of Weight of Paper.—In the earlier types of regulating box, the machine tender changes the amount of stock going to the machine when he wishes to change the weight of the paper, or when he finds that the weight has accidentally changed, due to the stock in the chest becoming thicker or thinner. Likewise, he changes the amount of water added to the stock in accordance with his observation of its behavior on the wire, especially during the formation or interweaving of the fibers. This, however, is only one of several adjustments he may have to make. In order to relieve the machine tender of some of this responsibility, and to get more dependable uniformity, several automatic regulating boxes have been devised.

The principal factor in securing uniformity of weight is uniformity of the consistency. As pointed out in the Section on *Beating and Refining*, the logical place to control the consistency is when the stuff passes the Jordan on its way to the machine

chest. By keeping the consistency uniform, regulation at the machine is greatly simplified.

15. A Simple Regulating Box.—A very simple regulating box is shown in Fig. 6. The stuff pump discharges through pipe E into compartment K. An adjustable gate G admits the required amount of stock to the mixing compartment or box M, in which it is diluted and mixed with white water. The amount of the white water admitted is controlled by a valve on pipe W, set by the machine tender in accordance with the condition of the stock. The excess stuff flows over partition B into compartment F, and goes back to the stuff chest through pipe H, There is usually a gate on the discharge L to the sand trap, screens, and machine. If the consistency of the stuff is uniform, this gate can be made to control the amount of stock furnished the machine; since with a constant head, the volume delivered depends only on the size of the outlet. It may here be mentioned that **stock** is stuff that has been diluted. The mixing of stuff and white water may take place in a separate stock box.
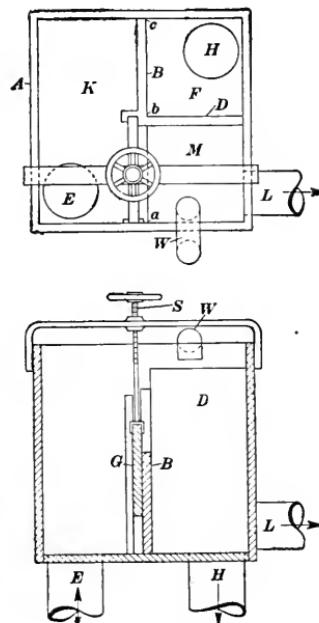
FIG. 6.

16. Conditions Governing Automatic Regulation.—Automatic regulation involves mechanical regulation at one or more of four points: (1) admission of white water at intake of stuff pump; (2) operation of gate G, Fig. 6; (3) control of valve admitting white water to mixing box; (4) operation of gate L. The principles generally involved are: the resistance to immersion of a float, which varies with changes in the consistency of the stock; the friction of the stock as it passes through a pipe, which varies with the consistency of the stock; the slight change in weight of a unit of volume of stock, which results from changes in consistency.

The advantage of a mechanical automatic regulator is that variations in consistency are detected in the stock *before* it becomes paper; the machine tender would not be aware of these

variations until he had weighed a sample of the finished paper. However, the use of a mechanical automatic regulator does not relieve the machine tender of the necessity of making proper adjustments when changing the weight, width, or speed of the paper, or in preserving the general character of the stock. The behavior of the stock on the wire may require furthur adjustment of consistency.

17. Regulating the Consistency.—It is unnecessary to repeat here the description of the consistency regulator, which was illustrated and explained in the Sections on *Treatment of Pulp*, Vol. III, and in *Beating and Refining*. The regulator there described will control the consistency of the stuff going to the machine chest to within 5% of the consistency desired. This is accomplished by keeping the stuff a little too thick in the beater or pulp chest, and by controlling the amount of white water or fresh water admitted to the suction side of the stuff pump. With stuff of accurately controlled consistency, it is only necessary for the machine tender to set his valves and gates for the amount of stock and diluting water that accords with the speed of the machine and the character of the stock. Variation in weight can then occur only because of mechanical trouble with the drive.

18. Automatic Regulator.—In Fig. 7, a regulator is shown which has been designed to regulate the volume of stuff furnished the machine as the consistency varies, in order that the weight of fiber supplied to the machine may be constant. Delivery from the stuff chest is through the pipe A to box B, any excess flows over the dam C, and is pumped or flows by gravity back to the machine chest through pipe D. The stuff for the machine passes the adjustable gate E, which is moved by pin F and levers G and H, the latter being actuated by the float K. The stuff passes down the spout L, works up around the float K, and into the annular ring M, from which it flows to the machine. The float may be weighted according to the usual consistency of the stuff; it sinks in thin stuff, and it is raised by the friction and greater density of thick stuff, thus opening or closing the gate E accordingly. No outside power is required to operate this mechanism, which is very simple. The amount of white water or fresh water used to dilute the stock must be regulated by other means.

19. Automatic Stuff Box.—The regulator shown in Fig. 8 is called an **automatic stuff box.** Stuff from the chest enters

compartment A and leaves it through outlet F, which is so
divided by the bottom of spout H that a part or all of the stuff
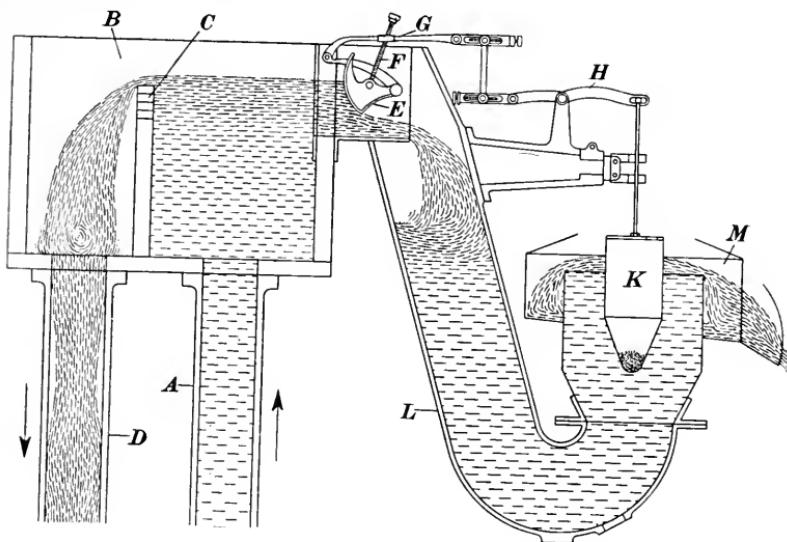
Fig. 7.

may go either to the overflow or back to the chest through B,
or it may go to the machine through C. A clean-out gate is
shown at G; it is operated by handle T.
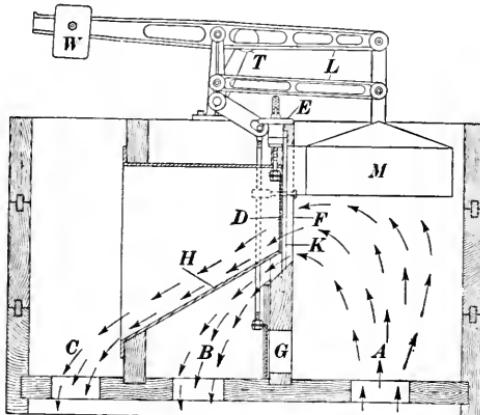
Fig. 8.

The relative proportions of the stuff going through B and C
are controlled by the dividing gate K, which lets more stuff into
B or C, according as this gate is raised or lowered. The move-

ment of gate K is caused by the float M, which is suspended from the levers L. When the stuff is coming through, the gate D is so adjusted by means of the hand wheel E that the required amount goes to the machine and the remainder goes back to the chest. The float is counterpoised by the weight W, which is adjusted to balance the float in stock of the proper consistency. If the stock becomes thicker, less fluid, its buoyant action is increased, the float rises, and the gate K, which is attached to it, also rises; the changed opening thus obtained admits less stuff to the machine and more to the chest. If the stuff becomes thinner, more fluid, more of it will then be required on the machine; its buoyant action then decreases, and the float M falls. This causes the gate K to move downward, partially closing the opening to the chest, which sends less stock to the chest and more to the machine. The stuff may be thinned to the proper state of dilution for machine operation by adding water at any convenient point after the stuff leaves the stuff box. The regulation of this water is not provided for in this apparatus, since the slight change in the flow of stuff required to maintain uniform weight of paper would make only an almost imperceptible change in the density of the stock on the wire.

SAVE-ALLS

20. White Water.—**White water** is the term used to designate the water that flows through the wire of the paper machine and into the save-all boxes under the wire; it is the water that is removed by the table rolls as the paper forms, and by the suction boxes. Naturally, this water contains considerable fiber and filler, and it should not be wasted.

As the white water collects in the save-all boxes, it flows, by means of wooden troughs, to the back, or driving side, of the Fourdrinier and into a box that is piped to the suction intake of a centrifugal pump. This pump discharges as much white water into the regulating box as is required to dilute the stuff in compartment M, Fig. 6. This constant circulation is also maintained in the case of a cylinder or board machine. There is, however, a comparatively large proportion of the white water that escapes the save-all boxes; this settles in a pit under the wet end of the machine, or it flows over the dams of a cylinder machine. It is often necessary to permit quite a large quantity

of stuff to flow to the pit; and if there is no means of recovering this waste, it ultimately finds its way to the sewer.

21. Paper-Mill White Water Flow Diagram.—A typical paper mill system is drawn for machines having trays and is shown with
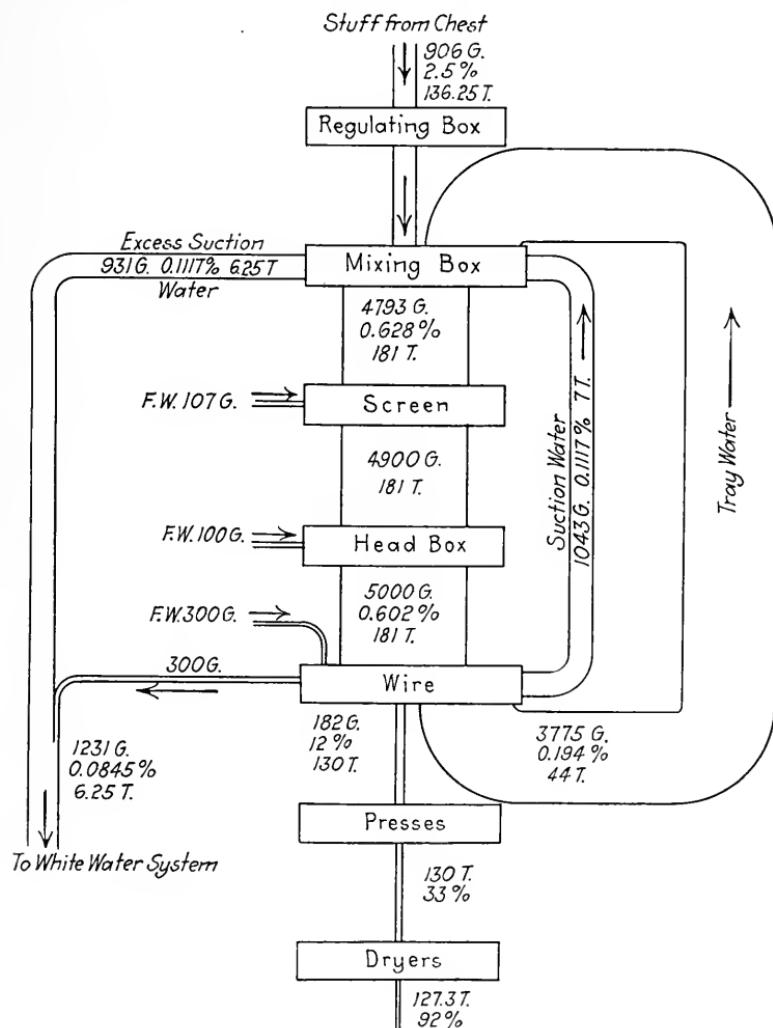
tray and suction water supplied to a mixing box having baffles so arranged that all the tray water is used before any of the suction water. The supply to the machine includes groundwood and sulphite pulp, the worked-up "broke" and the recovered stock

from the excess white water. The stock is shown as "air-dry" consistencies up to the dryers, purposely to bring out the "book figure" shrinkage between the "air-dry" pulp and the finished paper. This diagram shows where and how much fresh water is added, how much white water is removed, how much fiber is contained in it, and where it re-enters the system or is discharged. The width of the stream is proportional to the volume. Of course, if consistency figures vary from those given—and they usually will, the volume of water flow must be changed in proportion.

In this diagram, which is drawn for a 120-ton newsprint unit. the following abbreviations are used:

F. W. = fresh water
G = gallons per minute
% = consistency, air dry.
T = tons per 24 hours, including "broke."

A sulphite-mill system serves as a good outlet for excess paper mill white water. For a 25-ton pulp mill, 500 to 600 gallons per minute of the paper-mill water carrying, say, 3 tons of stock, could be used to advantage. Under this condition the loss from the sulphite mill will be greater; but still about 80% of the stock in the paper-mill water will be retained with the sulphite stock. The use of this paper-mill water also may necessitate added deckering or pressing equipment for the sulphite, mainly due to slowing up the stock.

Fig. 9.

22. Cylinder Type of Save-All.—Several types of **save-alls** are fully described in the Section on *Treatment of Pulp*, Vol. III, one of these being shown in Fig. 9. Here, a cylinder 4, covered with fine wire, is revolved in a vat 8, into which the white water flows, generally by gravity, through inlet 7. The white water flows through the fine wire covering of the cylinder mold, leaving the suspended fibers clinging to the outside surface. As the
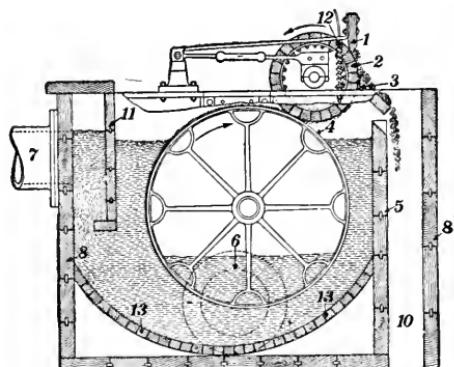
surface of the revolving cylinder emerges out of the water, it passes under a soft couch roll 2, which picks off the adhering
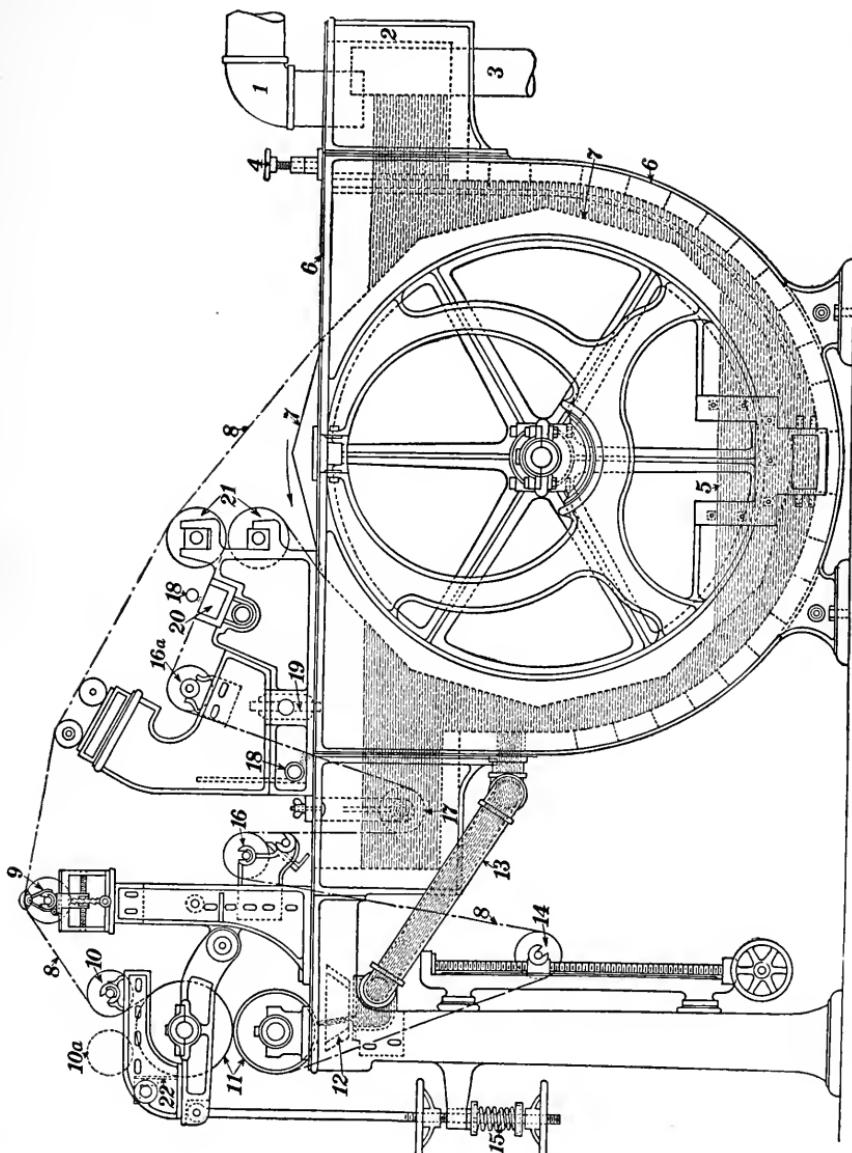
FIG. 10.

fibers from the wire.   The couch roll is, in turn, scraped by a wooden doctor 1, which is so inclined that the pulp fibers are

taken off the couch roll and guided by a board 3 into a passage 10. From this passage, pulp fibers thus scraped off are conducted to a convenient receptacle, as a truck, from which the pulp is shoveled into the beaters, or conducted in suspension to the white-water or stock system.

Many developments of this type of save-all are in use.   Fig. 10 shows a polygonal drum 7, wound with brass wire, which is covered for five-sixths of its perimeter by a part of the endless felt 8, in order to save a larger proportion of the finer fibers. This felt is of considerable length; it is carried out of the top of the vat on rolls, and the fibers are washed off by a shower pipe at a convenient point, or are scraped from a couch roll, as at 22. In another type, the collected fiber is blown off the face of the cylinder by means of a current of compressed air, which is discharged through a perforated pipe in a tangential direction against the outside of the cylinder.

Fig. 11 shows a cylinder revolving in a vat of white water 19. By means of interior air-tight compartments, which are connected to a suction pump, the water is pulled through the wire, and the

Fig. 11.

fibers are left behind on the surface of the wire when the air-tight compartments are under water.   At a certain point, 18, when these air-tight compartments are out of the water, they connect with the discharge of an air pump, and the fibers are blown off the surface of the wire, to slide down the doctor 6.   This type of machine is also used to thicken pulp.
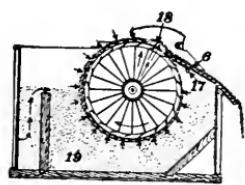
23. In all these machines, with the exception of the save-all where the felt is used, there is little or no salvage of the finer fibers and of the filling materials, such as clay, because these find their way through the mesh of the cylinder-wire covering. Where the felt is used, the loss due to the wear of the felt and to the expense of attendance (this latter item being chargeable to all types of save-alls) becomes an important consideration.

24. Settling Tanks.—A very important type of save-all that is largely used in book-paper mills is called the **settling tank;** its first cost is expensive, but this is more than compensated for by the small cost of operation, upkeep, and repair, with no parts to wear out or require renewing.

To take care of all the white water from a pulp or paper mill, the settling tanks must be of large proportions, in order to give all the white water sufficient time to stand long enough to settle. In some cases, the white water is distributed around an annular
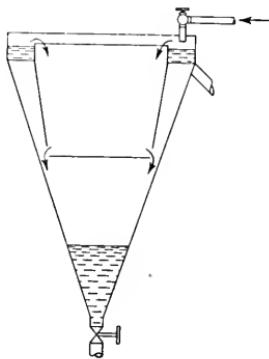
FIG. 12.
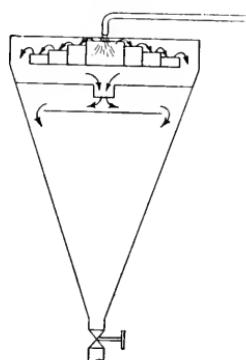
FIG. 13.
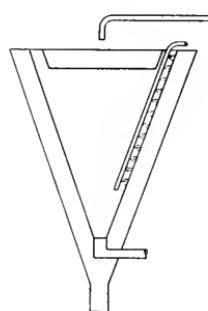
FIG. 14.
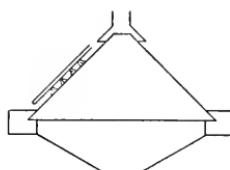
FIG. 15.
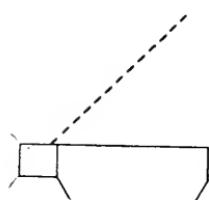
FIG. 16.
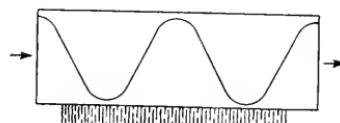
FIG. 17.

trough, Fig. 12, running on the outside circumference of the tank. When full, this annular trough allows the white water to flow slowly over into the tank, so as to prevent any undue agitation and permit the maximum settling effect. This type of save-all is

made conical in shape, the apex of the cone being the lowermost point, at which the sediment is removed through a valve.

Fig. 13 shows a more modern type, in which the white water enters at the center, and flows outwardly into a series of annular troughs until it reaches the outer trough, where the solids finally settle in the bottom of the inverted cone.

The settling type of save-all possesses the advantage of allowing the savings to be pumped back into the system, thus eliminating the labor involved in the save-alls previously described, where the savings are so thick that it is necessary to shovel them into trucks, from which they must then be forked into the beaters. Settling tanks must be large enough to permit their uninterrupted operation, in order that the white water may flow continuously into the tank, while the savings and clear water are flowing away continuously and separately. This requires that the tanks be about 20 feet in diameter and that the cone be about the same height, though even larger dimensions are preferable. The settling tank does not work right until it becomes full of white water, when the incoming water comes quickly to rest on top of the large body of water beneath it, and then the suspended matter begins to settle at once.

25. Inclined-Wire Save-Alls.—A commonly used type of save-all, which is made in many different forms, is easily built in the mill, and requires little or no power to drive it, is an inclined screen, of fine mesh wire, which is sometimes given a slight motion; it requires only intermittent attention, which involves merely the pouring of the white water. This type needs practically no attention at all, since the savings can be pumped back into the system in the same manner as in the settling tank, the wire screen replacing the settling action. It also has the advantage of low first cost. Figs. 14–17 show diagrammatically four forms of this type.

26. Fig. 14 shows the Whitham type. The diameter of the cone at the top is about 11 feet the diameter of the opening at the bottom is about 2 feet and the height of the cone is about 10 feet The speed of revolution, about 6 r.p.m., is not important; it simply revolves fast enough to allow the showers to clean the face of the wire. While the wires should be about 120 mesh, to save the maximum of fiber, they are often as coarse as 80 mesh, or, even, 60 mesh.

A save-all of this type, and of the dimensions given, can handle about 400 gallons of waste water per minute, which is the average amount of white water from a paper machine making 50 tons of paper per day of 24 hours, about 4500 pounds of paper per hour. The two figures are given, because the hourly figure is the maximum output, while the daily figure is the average output when allowance is made for breaks, etc.

The save-all shown in Fig. 15 is similar to that of Fig. 14, except that the cone is inverted from its former position, and the showers are on the outside, the water flowing on the outside of the cone instead of down the inside, as in the case of the former.

The most important thing in connection with an inclined save-all is the cleaning of the wire. If the cleaning is intermittent, it should be done at least once every 8 hours.

27. Fig. 16 shows the Nash type of save-all, in which the cone is replaced by a flat vibrating screen, situated at such an angle that the entering water flows down and through the screen; the savings are left on the surface, to be washed off by a shower pipe.

The Shevlin type of save-all is shown in Fig. 17. It consists of a revolving, fine-wire-mesh covered cylinder that contains a revolving worm. As the white water flows in at one end, the clear water escapes through the wire mesh, and leaves the savings in the interior; the screw (worm) gradually forces the savings along the interior of the cylinder until they are delivered out at the other end, where they fall into a suitable receptacle, from which they are pumped back into the system.

28. Save-Alls as Filters.—The savings and rejections may be pumped separately into the system at convenient points, or they may be permitted to run to waste, as desired. The save-all is sometimes used for straining or filtering purposes, in which case, the clear water that passes through the wire can be pumped into the water system that serves the mill, and the savings may be dirt that is allowed to fall from the screen save-all to waste.

The wire mesh that is used in the construction of these save-alls must be well supported with wire of about 14 mesh, to keep in shape; the only part that requires renewing is the fine wire, as it wears out; this is a good place to make use of old Fourdrinier wire. The capacity of the wire type of save-all, when used as a filter, is practically unlimited; a save-all of the size mentioned in Art. **26** will filter 2,000,000 gallons of water from all

solid impurities in 24 hours, and it will supply water for paper-machine showers and for similar purposes. The power required to drive this save-all is very small, a maximum of 3 h.p. being sufficient.

RIFFLERS, OR SAND TRAPS

29. Construction.—Rifflers, or **sand traps,** are wood troughs through which the stock flows from the regulating box to the screens. They vary in size and length, and in shape, according to the capacity of the machine and the relative position of the regulating box with respect to the screens. Note the position of the riffler in Fig. 2.

The bottom of the trap (riffler) is divided into sections by transverse strips of wood, which are frequently so inclined that their faces lean against the flow of the stock; this helps in the retention of dirt, or sand, as it sinks to the bottom of the riffler. In some narrow boxes, the wood strips are replaced with strips of zinc, slipped into slots in the sides of the trap; these can easily be removed for cleaning. The depth of the riffler, or sand trap, is from 18 to 20 inches, and the width is from 18 inches to 8 feet. The narrower sizes are usually of greater length, say from 30 to 50 feet; while the rifflers called *button catchers* may be longer, even, than 50 feet, when they are used to catch stitching wires in mills that prepare the stuff from old magazines. The wider traps are seldom over 15 feet long, being used in the preparation of fine writing and bond papers. The bottom of the trap is sometimes covered with old felt, to catch and hold the dirt, but this is of doubtful value. The rifflers should be carefully cleaned whenever the mill is shut down. If felts are used on the bottom of the riffler, they should be nailed down between the slats and carried up the sides, so that no dirt or stuff can accumulate underneath and break away at intervals, to cause breaks on the machine.

For the purpose of controlling the amount of water in the stuff, there may be two pipes at the inlet to the riffler, one for water and one for pulp from the regulating box, when the stuff is not diluted in the regulating box or in a special mixing box.

30. Two-Run Riffler.—Fig. 18 shows one type of riffler, or sand trap. The mixed water and fiber flows into the riffler through pipe A, and the pitch (slope) of the bottom of the riffler is only about 1 inch in 14 feet. Observe the shape of the strips B

that catch the heavier particles of sand. This riffler is divided into two runs by the central dividing board D, the total length of run of the stock being about 28 feet, and the width of each run being about 18 inches. The discharge pipe C leads to the screens. When the riffler is to be cleaned, the discharge pipe C is disconnected, the supply pipe A is put to one side, and the riffler is turned on its side, or even upside down, so a hose can be played into it and the dirt washed out. By turning the handle H, the worm W turns the worm wheel W_1, and moves the riffler over as far as is required. The worm wheel W_1 is keyed to the gudgeon (journal) G.
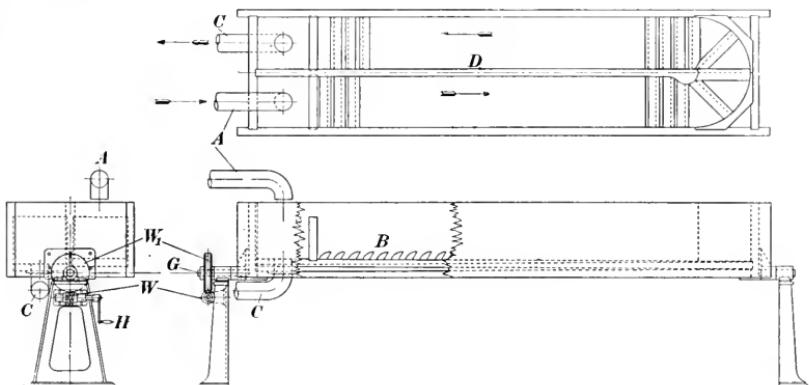
Fig. 18.

Other types of rifflers are illustrated and explained in the Section on *Treatment of Pulp*, Vol. III. Since rifflers are often made at the mill, local ideas and conditions may affect their construction. The student should refer to Figs. 1 and 2 constantly, to familiarize himself with the circulation of the stuff from the stuff chest until it becomes stock on the rifflers and is delivered to the machine.

31. Rifflers with Electromagnets.—Paper stock that is prepared from rags, especially if overalls are used, is likely to contain small particles of iron. This may also occur when waste papers, stitched with wire, are used. Particles of iron may likewise be present by reason of the abrasion of beater and Jordan bars. Such particles can be almost entirely removed from the diluted stock by placing an electromagnet across the riffler, just before the stock goes to the screens. When this is done, it is a good plan to make the riffler a wide, short box, in which the magnet is

placed, in order to have a shallow stream of water flowing over the magnet. A good installation is shown in Fig. 19.

Here A is a stream of stock in the riffler B; C is an adjustable baffle; arrow D shows the direction of flow of the stock; E, E are magnet pole pieces; F, F are magnet coils; G is a yoke connecting the two pole pieces; H is a wood support for the extractor; and
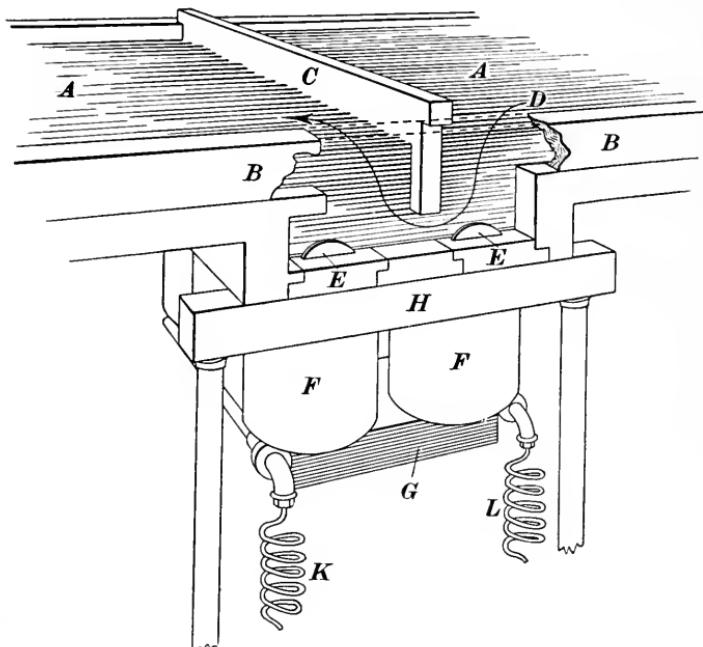
Fig. 19.

K and L are the lead wires. A plugged hole in the bottom or side of the magnet affords an opening for cleaning, when the current is off. Direct currrent is equired for an electromagnet.

SCREENS

32. Diaphragm Screens.—Before the paper stock finally enters the flow box, or head box, as it is sometimes called, ready to flow onto the wire of the paper machine, it is screened, for the purpose of removing as much as is possible of the dirt, lumps, slivers, etc. that may be present, and which have resulted from or have escaped during the process of preparation. Both the **flat,**

or **diaphragm,** and the **rotary** types of **screens** are used at this stage of manufacture. In either case, a difference in level between the inside and the outside of the screens causes the water in which the fiber is suspended to pass through a slotted or perforated plate.

In Fig. 20, the diaphragm screen is made to take 10, 12, or 14 plates, usually of bronze, which are 12 inches wide, 43 inches long, and about $\frac{3}{8}$ inch thick. These plates 12 form the top of a shallow box, the bottom of which is made up of a series of rubber diaphragms 22, which are supported on boards 14 and are separated by wood spacers 21, which, together with the strips 30, support the plates. The top of this shallow box is the bottom of the screen box, the sides and ends of which are numbered 10 in the illustration. The screen box rests on the frame 18, to which the diaphragms are nailed. The box and frame are clamped together by long threaded bolts (screen bolts) in such a manner as to make a tight joint all around. Two socket joints are provided on one side, so the box can be raised at intervals and washed with a hose. The diaphragms, which give the screen its name, are fastened by air-tight joints to the sides and ends of the box and to the cross beams 19. Rods 5, attached by blocks 23 to the centers of the diaphragm boards 15, and bearing at their lower ends a hard-wood toe block 7, ride cams 8, which have three or four corners. The cams are mounted on a shaft 2, which revolves at 125 to 175 r.p.m., thus agitating each diaphragm either three or four times for each revolution of a cam. The cams are so mounted on the shaft that their strokes alternate with one another. The hard-wood blocks, usually maple, are held by clamps 9; they are removable, since they require replacing as they wear out. The blocks are restrained from jumping away from the cams by the springs 27 and 28, and by the adjusting nuts 4.

33. The size of the slots in the screen plates depends upon the kind of paper being made, their width ranging from 8 to 25 thousandths of an inch (0.008″–0.025″); they are referred to as 8 cut, 25 cut, etc. The slots are wider at the bottom than at the top, and are cut about 4 or 5 to the inch; their length is about 4 inches. The screen is made with an adjustable dam 31, 32 at the outlet 16, to permit complete control of the level of the stock relative to the plates. The position of the plates being fixed, the use of the adjustable dam board 32 allows the operator to back
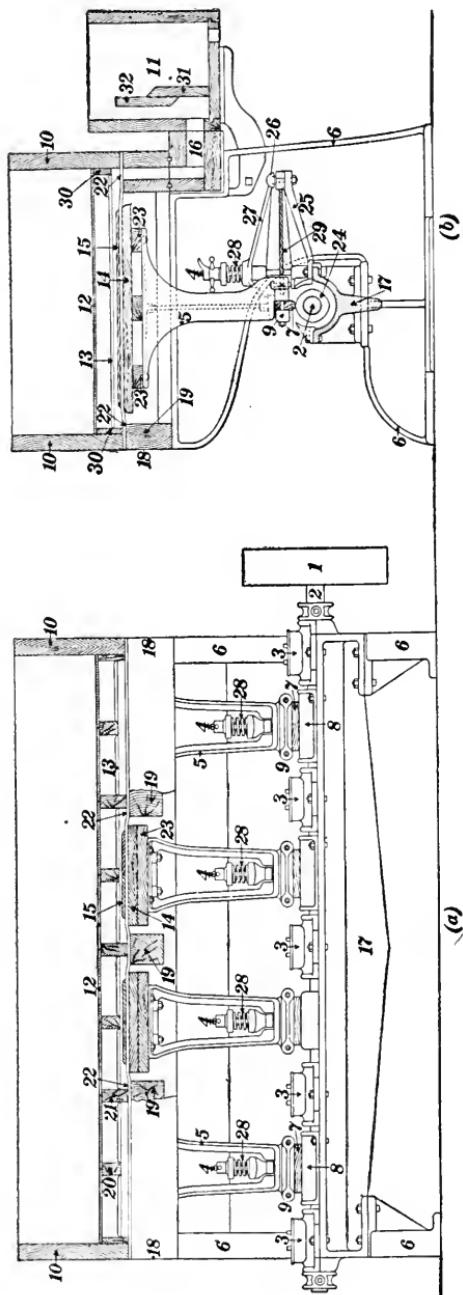
Fig. 20.

up the water and stock under the plates until the screening action is satisfactory.   If the stock level is too high, the diaphragm will shoot the stock back through the plates; if the level is too low, the capacity of the screen is decreased, as there must be enough surge to keep fibers from settling thickly on the slots.   The operator should adjust the dam while he looks down on the screen, while the screen is in operation.   Sometimes a variation in the sizes of the slots in the different plates is successfully used to increase the capacity of a screen.   When this is done, the oncoming stock is forced to follow a definite path, mapped out with baffles.   The plates having the larger slots are near the receiving end, where the stock flows freely and rapidly; the plates having the smaller slots are at the other end, where the flow of the stock is retarded and the stock has nearly finished its journey.   Stock is nearly always delivered to a screen at one end, there being a slight slope downwards of the plate surface to the other end.

Screens should always be kept clean; otherwise, they soon become filled with stock.   This not only decreases the capacity of the screen but it also increases the danger of lumps of stock accumulating.   In time, these lumps get into the flow box 11, Fig. 20, from which they find their way to the paper machine and are a frequent cause of breaks.

34. Care of Screens.—The screen plates are often ruined by careless workmen during the operation of cleaning.   Walking on the screens in hobnail boots (which catch in the slots), and banging the plates with hammers or pieces of belting, may force through the plates the material to be removed; but it is very likely to injure the plates, and the slots may be appreciably enlarged.   The only right way to clean screen plates is to raise the screen and patiently clear each slot with the cleaning tool that is supplied by the screen-plate makers, and which is just large enough to go into the slots.   The plates should then be well washed with a hose.

The screens should be well washed at least once a week; this means that the boxes must be lifted out, the slots cleaned, and the interior of the diaphragms and all inner parts of the screen boxes thoroughly cleaned of all slime and traces of old stock. If this be not done periodically, the dirt, slime, and accumulations of stock will get on the wire and cause many unnecessary breaks and much spotted paper.   The slime that collects in the screens

is a peculiarly fertile source of trouble; it forms a transparent spot, which will generally become a hole somewhere on the machine. These slime spots are a sign of dirty screens.

It is well to have a set of boxes for each screen, with plates of different cut. It may even be desirable to have a duplicate box for each screen, to allow a clean screen to be put in place quickly, especially when using long rag stock. Care should be taken that the screen diaphragms work right; see that the outlet dams are properly adjusted, and be sure that the hard-wood blocks do not ride, for, if they do, they cannot give the diaphragm the proper range of action.

The use of a shower of water to wash the large slivers, shives, and dirt to the lower end of the screen is preferable to, and generally quite as satisfactory as, the use of scrapers. If scrapers are used, they should be made of softer material than the metal of the screen plates. The plates should be carefully handled and cleaned; and, if the slots are enlarged by reason of excessive cleaning, the plates should be discarded. Screen-plate manufacturers can re-cut old plates to some standard slot size. The screws must fit in the spacer pieces and sills, so each screen plate may be rigidly held in its place. It is almost impossible to keep screwed screen plates in condition after the sill screw-holes get worn; in any case, there is a tendency for small screws to get lost or badly strained when the screens are cleaned. There are many designs of screwless screen plates, which are fastened in place by beveled or rabbited cleats that fit specially edged screen plates. If not too complicated, all such designs are superior to the screw type.

Care should be taken to screw or clamp securely to the screen frame the top box that carries the plates, using a good water-tight packing. The diaphragm screen is still very commonly used, in spite of many obvious drawbacks.

35. Rotary Screens.—Many paper makers prefer rotary screens because, with this type, it is possible to keep the screen plates continuously clean by means of a good shower. It is only of late years that rotary screens of simple design and heavy construction, qualified to give large capacity and long service, have been available. Several makes of rotary screens that are proving satisfactory in operation are now on the market. They are of two types; namely, the inward-flow screen, and the out-ward-flow screen. Both have their own peculiar method of

agitating the stock, to assist it in flowing through the plates and in preventing the settling of fiber.

The inward-flow type of rotary screen is naturally of greater capacity than the outward-flow type, and it is best adapted to screening dirty stock.   It is used for newsprint, book, sulphite bonds, bag, wrapping, board, roofing, and coarse papers generally. The outward-flow screen is better suited to the making of fine papers, such as ledgers, fine writings, and bond papers containing a large proportion of rag stock.

36. Inward-Flow Rotary Screens.—Fig. 21, is an end view of a frequently used inward-flow rotary screen.   The stock enters through flow boxes A and B, both being placed above the vat and discharging downwards against a revolving cylinder C.   The stock passes through the screens that form the shell of the cylinder, and it then flows through an open journal to

a discharge box at the rear end, which is connected to the flow box of the paper machine.   There is a difference of level between the stock that is inside and that which is outside the cylinder.   Stock that will not pass through the screens settles in drain E, from whence it flows to the auxiliary screen.   The latter is a specially designed, small, flat screen, where the good fibers are washed through and recovered.

FIG. 21.

The slots in the revolving screen are cleaned by the shower pipe H.   The pan I serves as a guard against splashing, and tray J catches the water that strikes the cylinder and falls back.   The body of the vat K is made of boiler plate, and is copper lined; it is supported by two semicircular brackets L, one end of which is, in turn, supported by two vertical plate springs M, and the other end is supported by a double pivot N.   From this pivot, the shake arm O extends to the eccentric P, which runs at about 350 r.p.m.   This vibration of the screen tends to churn the stock and urge the fibers through the slots.
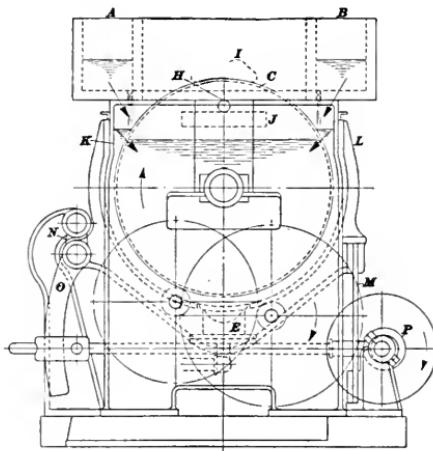
37. Another type of inward-flow screen depends for agitation on a difference of shape between the rapidly revolving drum and the interior of the vat. Under certain conditions, this causes a series of varying suctions and pressures in the screen cylinder, which reproduces, in a measure, the action of the diaphragms in the flat screen. A screen of this type is shown in Fig. 22, and it requires no eccentric or mechanical vibratory motion. The agitation of the stock is caused by the revolving of the polygonal drum A at a higher speed and in a direction opposite to that of the screen cylinder B. Referring to the diagram, Fig. 22, the distance DH is less than the distances FG and EK. When drum A revolves in the direction of the arrow and the point D falls on a radius drawn through E, the space between E and the cylinder will be smaller than when the drum is in the position shown in the cut, and a pulsation outward will take place. When the point C passes the point on the radius indicated by the point F, and goes on to the position of the point D, the space between the drum and the cylinder becomes larger, and an inward suction takes place. In other words, the level of the stock outside of the drum is caused to rise and fall slightly, provided the drum is not entirely submerged, which creates a suction that causes the stock to flow into the drum.
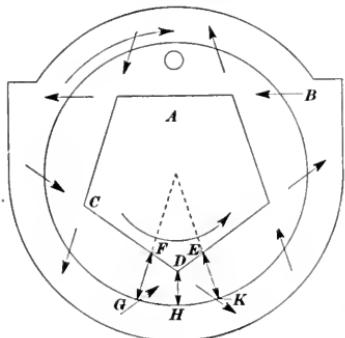
FIG. 22.

38. There are several makes of screens in which the stock is agitated by means of immersed plates. In one, a vertical plate on either side of the cylinder is moved by rods that pass through rubber diaphragms in the side of the vat. In another type, a horizontal plate under the cylinder, and bent concentric with it, is vibrated up and down by an eccentric having an adjustable throw. Still another make has a plunger, with a reciprocating motion, in a chamber below the screen; this creates suction alternately on each end of the screen cylinder.

39. Outward-Flow Screens.—A good example of the outward-flow screen is shown in Fig. 23; it is designed and built for screening high-grade rag and long-fibered slow stocks. The stock enters the cylinder through pipe M, at one end; it then drops to

the bottom of the cylinder, passes through the slots into the trough N, from whence it goes to the paper machine. The rejections are carried up with the revolving cylinder A, and are washed out through the discharge pan Q by the shower V. The shaft S, driven by eccentric H, is fitted with a lever F at either end; it jerks the straps B, on which rest circular projections C of the cylinder A, which would be journals if they turned in bearings. This jerking of the straps vibrates the cylinder, and it hitches it around at the same time.

40. Another mechanism, by means of which the screen itself is made to vibrate, is shown in Fig. 24, where S is the screen and T is the vat. The screen is carried on an arm A, which is pivoted about a
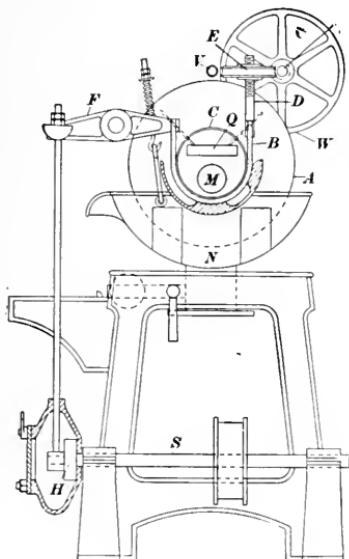
Fig. 23.
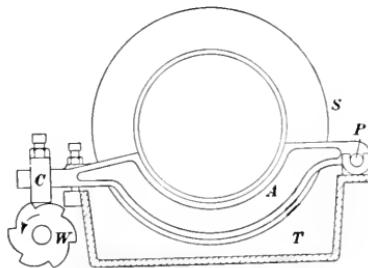
Fig. 24.

point P; to the other end is attached a pawl C, which engages with an interrupted cam, or ratchet wheel W. As the ratchet wheel revolves in the direction indicated by the arrow, the pawl is lifted; and this, in turn, lifts the arm and screen. When a point of the tooth is passed, the pawl, arm, and screen fall; this jars the screen, and the jar loosens any fiber that may have clogged in the screen. The screen is revolved by a ratchet wheel that is attached at one end of the cylinder.

41. A popular English screen dithers (vibrates) the cylinder by means of an adjustable, rotary-eccentric, center bearing at one end. The shaft, which makes 600 r.p.m., carries in an eccentric position a circular hub that turns in a Hoffman ball bearing, which is attached to the spider that supports one end of the cylinder.

42. Outward-flow screens are thus seen to require that the
screen cylinder be agitated to assist the flow; but with inward-flow
screens, there are also available several other methods of agitat-
ing the stock.   An outward-flow screen is cleaned by a shower
pipe outside the cylinder.

The principal differences in rotary screens lie in ruggedness
and simplicity of design, difference in the methods of creating
suction and agitating stock, and in the method of removing the
rejected stock.

A very good discussion of screens is given in the Section on
Treatment of Pulp, Vol. III.

THE MODERN PAPER MACHINE

ORIGIN AND DEVELOPMENT

43. Robert's Invention.—The process of making paper by
hand, which was the method in universal use until the invention
of the paper machine by Louis Robert, in France, in 1799, is
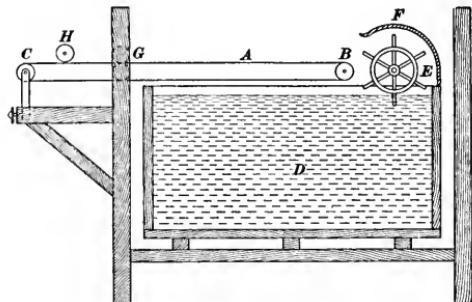
Fig. 25.

described in the Section on *Handmade and Special Papers,* Vol.
V.   For both handmade and machine-made paper, the prepara-
tion of the stock is the same, and has been fully explained in
previous Sections.

The first paper-making machine that was designed by Robert,
see Fig. 25, consisted of an endless wire cloth *A*, which passed
between two rolls *B* and *C*.   The position of *B* was fixed, while
C was adjustable, so the wire could be stretched.   The beaten
pulp in vat *D* was thrown up by a revolving fan *E* against the
baffle plate *F*, which distributed the pulp and water in an even

stream on the moving surface of the wire cloth. As the wire cloth *A* traveled slowly forward, the water passed through the wire, while the small squeeze rolls *G* completed the preliminary de-watering. The receiving roll *H* reeled up the wet sheet until a sufficient length had been obtained, 50 feet being generally accepted as the practical limit. The roll was then removed, the paper unwound, passed through some press rolls, and hung up to dry. A working model of this machine was made; but, as is always the case with a new design, it was not perfectly satisfactory. Robert was granted a bounty of 8000 francs to assist him in his studies and experiments; and he sold his interest in his patent, and his model of the machine, to his employer, M. Leger Didot, of Essones.

44. Early English Patents.—M. Didot realized the greater possibility of successfully perfecting such a machine in a country free from governmental strife, and doubtless strongly urged thereto by his brother-in-law, John Gamble, an Englishman, he sailed for England in the summer of 1800. Didot had some mechanical ability, and it is possible that some improvements on the original machine were made by him before leaving France. In England, Didot was fortunate in securing the help of Mr. Bryan Donkin, a man well qualified by his mechanical training to perfect the details of a machine of this type.

45. On April 2, 1801, English patent No. 2487 was granted to John Gamble for the improved paper machine, the title of the patent being: "An invention for making paper in single sheets without seam or joining from one to twelve feet and upwards wide, and from one to forty-five feet and upwards in length."

Further improvement in design finally resulted in a new patent, No. 2708, dated June 7, 1803, issued by the English government to John Gamble for "Improvements and additions to a machine for making paper in single sheets without seam or joining from one to twelve feet and upwards wide and from one to fifty feet and upwards in length." In the autumn of the year 1803, the first paper-making machine ever to be built and successfully operated, was started in Frogmore, England; in 1804, another successful machine, practically a duplicate of the first, was put into service at Two Waters, England.

46. In 1804, Messrs. Henry and Sealy Fourdrinier purchased the remaining interest of Didot and Gamble in the improved

Robert machine.   Henry Fourdrinier was granted patent No. 2951, on July 24, 1804, for "The method of making a machine for manufacturing paper of indefinite length, laid and wove with separate molds."   On August 14, 1807, an Act of the British Parliament gave an extension of the patent rights obtained by the Fourdriniers for invention of making paper by machinery.   In this Act, the machine described by John Gamble in the specifications of his patents, Nos. 2487 and 2708, together with the added improvements, were all fully described and illustrated by diagrams.

During the year 1808, John Gamble assigned to Messrs. Fourdrinier all his rights in the patents as extended by this Act of Parliament, thus making them the sole proprietors of the patents covering the only successful paper-making machine in existence.   So the machine invented by Robert, promoted by Didot and Gamble, designed by Donkin, and financed by the Fourdriniers, came to be known, and continues to be known, as the Fourdrinier machine.

47. The Donkin Machine.—The first Donkin machine is illustrated in Fig. 26.   The mixture of pulp and water, kept in a state of agitation, flowed from the vat A, which is like a modern
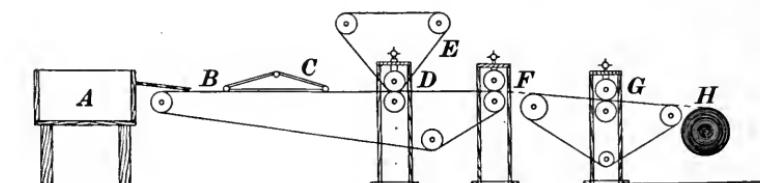
FIG. 26.

flow box, through pipes and onto the endless wire cloth B, between the endless deckles C.   The wet sheet of paper, having lost its excess of water, was passed between the squeeze or couch rolls D, as in the Robert machine, to be further de-watered; but, in this case, the work was better accomplished by reason of the traveling upper felt E.   This felt, the ancestor of the couch-roll jacket, also improved the firmness of the wet paper.   The paper then traveled to the press rolls F and G, and then was finally wound up on the reel H.

48. First Machines in America.—The first Fourdrinier machine in the United States appears to have been imported from

England, in 1827, by H. Barclay, of Saugerties, N. Y. This machine was a Donkin machine, 60 inches in width. A second Fourdrinier machine, 62 inches wide, was installed in this mill in 1829; but the second machine to be erected in the United States was imported from England and set up in the Pickering Mill, in Windham, Conn. This latter machine was copied by Phelps and Spafford, of Windham, and soon after that by Howe and Goddard, of Worcester, Mass. The Fourdrinier machine did not come into general use until several years after its first successful operation; even in England, only ten machines were made between 1803 and 1812, and only twenty-five more were built in the next decade. It was not until about 1830 that this great invention finally came into its own.

It is noteworthy that, in the early days, the cylinder machine patented by John Dickinson, in 1809, received more attention from mechanics and inventors in the United States than did the Fourdrinier. The supporting of the wire by table rolls in the Fourdriniers, and the use of these rolls in hastening the evacuation of the water, does not seem to have received the attention these features merited; and, in so far as the writer can find, no patents were issued covering these points. In fact, it is doubtful if many paper makers today realize to any greater extent than did the earlier generation the importance of the action of the table rolls.

49. Improvements in the Earlier Machines.—In 1826, Mr. Canson, in England, applied suction pumps to the Fourdrinier machine, to cause a suction underneath the wire on which the paper was formed, in order to assist in the removal of water. This invention really was an adaptation from the Dickinson cylinder machine.

It was not until the years 1889 and 1890 that the modern machine was perfected, which, with all its improvements, is essentially the same machine as the original of Fourdrinier and Donkin, with the addition of the cone drive and the steam-drying cylinders. Among the older paper makers, there still lingers the memory of when the paper dryers were headless cylinders, with a wood fire in each one. Steam cylinders for drying paper were first used by Crompton in England, in 1823.

The dandy roll was invented by J. Marshall in 1826. In 1820, Barrett invented a method of making rolls true by grinding them together, using water and emery.

FOURDRINIER PART OF THE PAPER MACHINE

GENERAL DESCRIPTION

50. General Data.—A skeleton outline of the Fourdrinier part of a modern paper machine is shown in Fig. 27. The flow box, or head box, 1 receives the prepared stock, which is screened and mixed with a large proportion of water. On a slow-speed, fine-paper machine, the contents of the flow box will consist of about 1% of fiber and 99% of water; while in the high-speed, news machine, it will consist of about $\frac{1}{2}$% of fiber and $99\frac{1}{2}$% of water, a ratio of water to fiber of 199 to 1, say 200 to 1. The stock flows from the flow box 1 to the apron 2, and from thence, to the wire 3, which moves on from the breast roll 4 to the support of the table rolls 5.

51. Course of the Wire.—The wire, partly hidden by the shake rails, travels from the breast roll 4 over the table rolls 5 and suction boxes 6, under dandy roll 7, over guide roll 8, between couch rolls 9 and 10, and comes back over wire roll 11, under stretch roll 12, over and under more wire rolls, and so back to the breast roll 4. The couch roll 9 is driven mechanically; this, in turn, drives the wire, which acts as a belt and drives the other rolls. The guide roll may be outside and under the wire near the breast roll. The table rolls 5 are supported by the shake rails 13, which carry bearings that are so adjustable that the rolls just touch the wire without lifting it. The shake rails up to the last table roll, together with the breast roll and several wire rolls, are supported on the frames K, which are pivoted at H, and are raised or lowered at the other end by some device, such as the screw-and-worm gear W. Sometimes the pivot is situated beyond the suction boxes. A shaft that extends across the machine connects the front and back gears, which move both sides the same amount. The shake rail is jointed just past the last table roll, at H, so the breast roll and front part of the wire can be given a jerky, horizontal motion, or *shake*, which assists the fibers to interweave in all directions, instead of flowing parallel to the direction of the wire travel.

The rubber deckle straps D, which have a square cross section, ride on the wire and form a tray for the paper stock, returning over the deckle pulleys E and through the wash trough F.
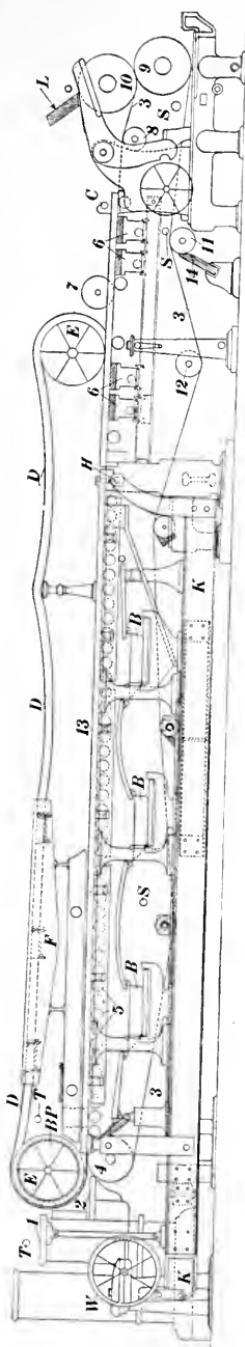
While the stock is being carried along by the wire, most of the water passes through it, under the influence of gravity and by the action of the table rolls, and flows into the white-water trays or boxes *B* (sometimes called save-alls), and usually goes to the white-water pump; more water is removed by the suction boxes 6, and a little more still by the couch rolls 9 and 10, which also press the fibers together.

52. Taking the Paper from Wire to Felt.—The paper is now sufficiently formed and firm enough to be carried to the first press felt. This latter operation is simplified by cutting the sheet into two strips, one about 1 or 2 inches wide, by means of the **cut squirt** *C*, which is simply a nozzle that directs a fine jet of water upon the soft web of paper. The reason for cutting the strip is that the machine tender can more
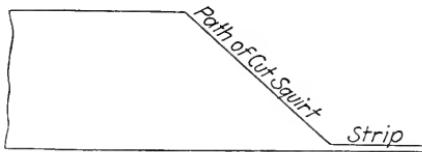
FIG. 28.

readily pick up this ribbon than he can pick a wide piece off the wire: he lays it on the first press felt; and when this strip is successfully carried onto the wet felt, the cut squirt is pushed across the machine, carrying with it its feeder hose, which is supported in a long slotted pipe that stretches across the machine, thus cutting the paper all the way across. Since the paper is traveling toward the couch rolls at the same time that the cut squirt is pushed across it, the paper is

FIG. 27.

cut diagonally, about as indicated in Fig. 28. It is evident that if the narrow strip be on the wet felt, the rest of the paper must also follow it into place.

If the machine is not equipped with a cut-squirt, the paper is placed on the press felt thus: The machine tender pats the edge from the wire, with the palm of his hand or with a piece of wet broke, which he slaps down so as to create enough suction to lift the paper. This tears a narrow strip, which he widens by lifting it skillfully at an angle. The back tender then tears off a bit of the inside edge and pulls his part toward the wire and also toward the back of the machine. This is repeated till the first narrow strip going to the felt is widened to the whole width of the sheet. It is a very delicate operation, requiring skill and patience.

As it leaves the lower couch roll, the return wire passes under a strong shower, which is situated over wire roll 11. If the paper is not yet ready to be passed onto the wet felt from the wire, or if it be broken between the couch rolls and wet felt, it will stick to the wire. At roll 11, all paper not washed off will leave the wire and will stick to the smooth surface of the roll. The doctor, or scraper, 14 scrapes all the paper off roll 11, so that it falls into the white-water pit, or box, underneath the wire at this point. If lumps stick to this roll, they may cause bulges in the wire and produce much trouble. The wet-paper broke collected in this box, or pit, flows to the save-alls, to the white-water pump suction, or to the beaters; in some mills, it goes to waste. Circumstances decide what shall be done with it.

53. Up to this point in the description of the Fourdrinier, no mention has been made of the slices, which are situated near the apron and which control the depth of the stock on the wire. These, together with the guard board L, the stretch roll 12, the wire rolls, the Fourdrinier elevating mechanism K, and the save-all, or white-water, boxes B, will all be fully described later. The dandy roll 7 (also shown in detail in Fig. 41) rests lightly on the wire where the wire passes the first or second suction box.

The pressure couch rolls 9 and 10 are sometimes replaced by one suction roll, which is described later. The wire is kept as clean as possible by continuous showers of fresh water, thrown on it by the shower pipes S. Spray pipes T are placed over the flow box and apron, to break down with fine sprays of fresh water the froth that is sometimes formed.

54. Right- and Left-Hand Machines.—A paper machine is either a **right-hand** or a **left-hand machine.** If one stand at the dry, or calender, end and look toward the wet end, a right-hand machine will have the drive on the right side of the machine, while a left-hand machine will have the drive on the left side of the machine. It will be noticed that, on a right-hand machine, the machine tender lifts the paper from the wire to the first felt with his right hand; and uses his left hand on a left-hand machine. The left side of a right-hand machine, or the right side of a left-hand machine, is called the *front,* or *tending side.*

DETAILS OF THE FOURDRINIER PART

FLOW BOX AND APRON

55. The Flow Box.—Some paper makers prefer to call this part of the machine the **head box** or **breast-roll feed box,** because
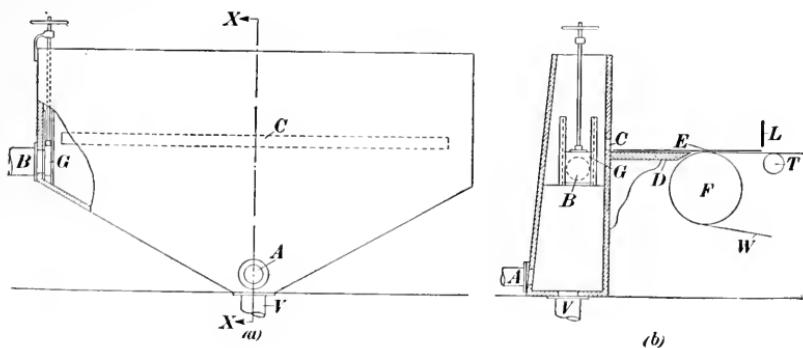
Fig. 29.

the box at the side of a flat screen is also sometimes called a **flow box.** Its purpose is to convert the rapid flow of stock in pipe G, Fig. 2, into a smooth, flat stream that will flow out evenly, without eddies, to the full width desired on the wire. It also provides a head that will be sufficient to cause the stock to emerge at a speed that approaches that of the wire.

There are many designs of flow boxes, the tendency being toward simplicity, as shown in Fig. 29. Here the stock enters at A, and as it fills the flare of the box, its velocity diminishes. The stock rises in an even flow; it overflows at B, controlled by

the gate G, into the white-water box W, Fig. 2, or to waste, until the machine tender is ready to start the wire. An opening V serves as a washout for cleaning.

56. Flow Boxes with Baffles.—On some machines, the flow box has a series of *baffles*, as shown in Fig. 30, to eliminate eddy currents. The stock enters at A, passes up over the first baffle, under the second, and then onto the apron D, through slot C. The edges of baffles should be rounded. Outlets V are provided at the bottom of each division, which discharge to the sewer, to the white-water tank, or to the pump intake; this takes care of
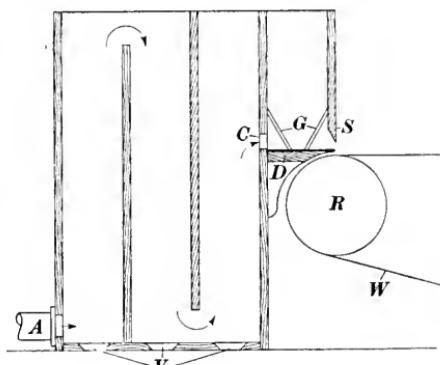
FIG. 30.

the stock before the wire is started, and it prevents flooding the wire in case of a sudden shut down. Parts G and S are explained later; they apply particularly to news machines.

57. A row of holes or a slot C, Fig. 31, and (b), Fig. 29, sometimes controlled by a gate, feeds the stock to the machine. The space between the flow box and the wire is bridged by an **apron** or apron cloth E; this is supported as far as the breast roll F by the **apron board** D, which is fastened by brackets to the front of the flow box. A part of the box front, or merely the board and brackets, may be made adjustable, so as to respond to any change in the inclination of the wire. On some machines, the apron board, and on some the whole flow box, is attached to the Fourdrinier part.

The apron E may be of oilcloth, fabrikoid, or rubber-coated cloth; it must be thin, flat, and without wrinkles, and it must fit snugly to the deckle frame; it must form a water-tight connection, and one that will permit adjustment of deckles when the

width of the sheet is to be altered.   This last is difficult, especially
if the Fourdrinier frame is shaken.

58. Putting on the Apron.—The apron is put on as follows: A
strip of dryer felt M, wide enough to reach from the opening of
the flow box to within about 3 inches of the first slice L, is so laid
down that it reaches from edge to edge of the apron board and
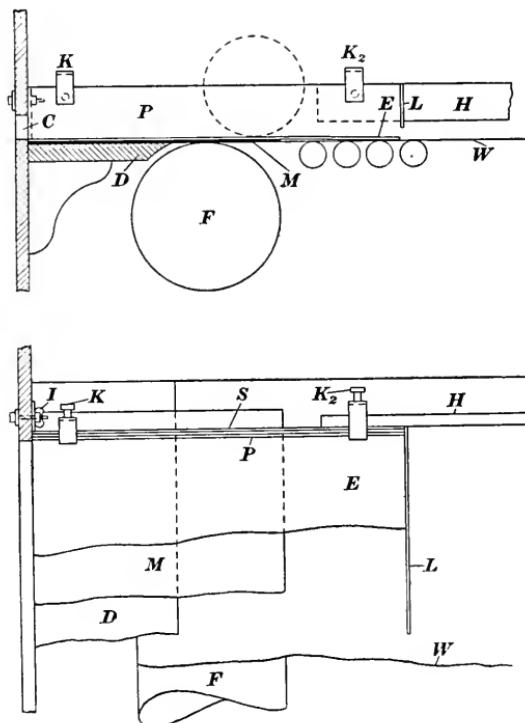
<p style="text-align:center">Fig. 31.</p>

of the wire W; on top of this is laid an apron-cloth strip E, wide
enough to reach from the flow-box opening to within 1 in. of the
slice.   (Some machine tenders bring the edge to the slice.)
Both felt and cloth are tacked to the apron board, or are held by
a strip of brass, screwed down; tacks are dangerous.

The end of the apron should not come directly over a table
roll, since the deckle strap rides the edge and will cause wear of
the apron and make bad edges on the paper.   Side pieces P,
of brass or other suitable metal, are bent and fastened to the face
of the flow box by bolts or thumb nuts I; there are slots in the

metal that permit sidewise adjustment. The side pieces form
the sides of the stock-channel to the slices; they are fastened to
the inside of the deckle frame H, on either side of the machine,
just inside the deckle straps. The edges of the apron E, on
each end, may be carried up straight and held tight against the
side plates by a strip of metal S, inside plate P, held in place by
a clamp K at the flow box and by another clamp K_2 at the deckle
frame H; this clamp grips the side plate, apron, and inside plate
to the deckle frame.

Sometimes the apron is allowed to stay flat, and the joint is
made at each side by a separate piece of apron cloth, about 18
inches wide, which is allowed to lap over on the apron; a piece of
wool felt between the two pieces of apron cloth, sewed to the
upper one, helps to make a tighter joint. Sometimes a strip
of metal is laid flat on this joining piece, to get a square corner;
this, however, is considered poor practice.

59. Changing Width of Paper Sheet.—When making only
a small change in the width of the sheet, the clamp on the deckle
frame is loosened until the deckle is shifted, the slack of the
apron is taken up, or more let out, and the plates are again
clamped in place. For a large change in width, it may be neces-
sary to shift the connection at the flow box. The flexibility
of the side plates provides for the shake movement.

60. New Design of Flow Box.—There are some new designs
of flow box, which operate under a considerable head and have
a spout that is designed on hydraulic principles; these boxes
deliver a smooth current of stock to the wire, without eddies or
ripples, and do not have an apron. The most recent develop-
ment is embodied in the newest newsprint mills in Canada, where
the front of the flow box is formed by the slice (see Art. **72**).
In Fig. 30, the slice S forms the front of a box, the bottom of
which is the apron board D. In place of the apron, a brass
plate that forms the edge of the apron board overhangs the
breast roll as far as the top of the roll, and is about $\frac{1}{2}$ inch above
the wire. The edge of the slice, which is sharp, comes exactly
above the edge of the plate, forming a *standard orifice*.[1] Wood or
metal grids G help to eliminate eddies and ripples. The deckle
straps come back against the ends of this slice box, and they are
held close to it by single-flange deckle-strap pulleys D, Fig. 32.

[1] See Part 4 of Section 1, Vol II.

A small piece of rubber cloth, extending about 6 inches from the slice, makes a square corner, and it keeps the stock from leaking under the deckle strap before the strap is flat on the wire. The slice plate is adjustable, to provide for two widths of the deckle; and the depth of the stock, which is the *head* in the slice box or pond, can be so adjusted as to control the velocity of emergence, and to make it accord with the speed of the wire.

SOME TROUBLES THAT CAUSE BREAKS

61. Soft Lumps.—It is well to note here some of the causes that make the paper break, causes due to conditions described up to this point. There are often **lumps** in the stock as it flows to the machine, and these may be either hard or soft. The **soft lump** is a new, thick blotch of stock, which has gradually accumulated either in the screen troughs to the flow box or in the flow box itself. These lumps occur when there are not a sufficient number of water jets in use to keep the stock from settling, and where fibers catch on splinters, screw heads, etc. After a lump becomes too heavy, it begins to flake in pieces, and passes from its lodging place into the liquid. It is then too thick to disintegrate again before it reaches the wire; and the result is that when it passes under the dandy roll or between the couch rolls, the extra thickness causes a crushed spot that breaks away from the rest of the sheet, often breaking the sheet at this point, or else causing it to break as it passes through the machine. Soft lumps can be prevented by removing splinters, etc., and by using the water hose occasionally, thus washing the stock clean from its resting place, when the resting places are known.

62. Hard Lumps.—**Hard lumps** are dark in color; they break away from accumulations of stock that have been gathering for days—sometimes for weeks. These accumulations are found, as a rule, between the screen plates and the screen diaphragms; and they may be in the lower corners of the stock trough, the flow box, or even in the apron. The remedy is to clean these parts often enough to prevent such accumulations; this should be done at least once every week.

63. Slime Spots.—**Slime spots** will often cause breaks; these spots come from the inside of the screens, from the pumps, and from the pipes on the entering side. Slime spots slip through

the screen plates, when the plates are old and in poor condition, because the slots are then so large that the slime passes readily.

64. Thin and Heavy Streaks.—The paper breaks where there are thin places parallel to the edge of the sheet. These thin places are due, sometimes, to the slice not being evenly adjusted or to the apron cloth not lying flat, which allows the stock to rush onto the apron and under the slices in eddying currents; this causes flow on the wire in several directions, and leaves **heavy** and **thin streaks** in the finished sheet of paper. However, the principal cause of these thin and thick streaks is a poorly designed flow box that allows eddies and cross currents in the stock as it flows to the wire. The only cure for this is so to re-design the flow box that the rush of stock onto the wire may be controlled. A perforated board, or grid, put in the last section of a flow box divided into compartments by baffles that are level with the top of the apron, will break up these large eddies and currents into many smaller ones, and the stock can then go onto the wire in a quiet, uniform flow. A row of pins or fingers on the apron board may also be used for this purpose, but it is best to avoid obstructions. A new, nozzle type of orifice has an adjustable flexible lip that works well.

65. Compartments in Flow Box.—Flow boxes in slow-speed machines frequently have but one compartment, as in Fig. 29. With medium-speed machines, two-compartment flow boxes can frequently be used. In the case of high-speed machines, three- and four-compartment flow boxes are needed, see Fig. 30, because the necessarily rapid flow of the liquid is harder to control.

THE DECKLE

66. The Deckle Frame.—Fig. 32 shows a deckle frame and the deckle parts. The side elevation (*b*) shows how the **deckle frames** *F* are supported on the **shake rails** *T* by the tubes *L*; it also shows the adjusting screws *S*, which serve to fasten and level the frame. By turning the handle *H*, both cross rods *A* are turned simultaneously by means of the four equal bevel gears (miter gears) *B*. Each of these cross rods is provided with a long screw thread on one end, the screws traveling in nuts that are fixed to the sleeves *Y*. Spur shafts *M* connect the bevel gears and keep the deckle frames parallel. When the slice

clamps are loosened, the turning of the handle moves the
frames in or out, according to the direction of turning. Each
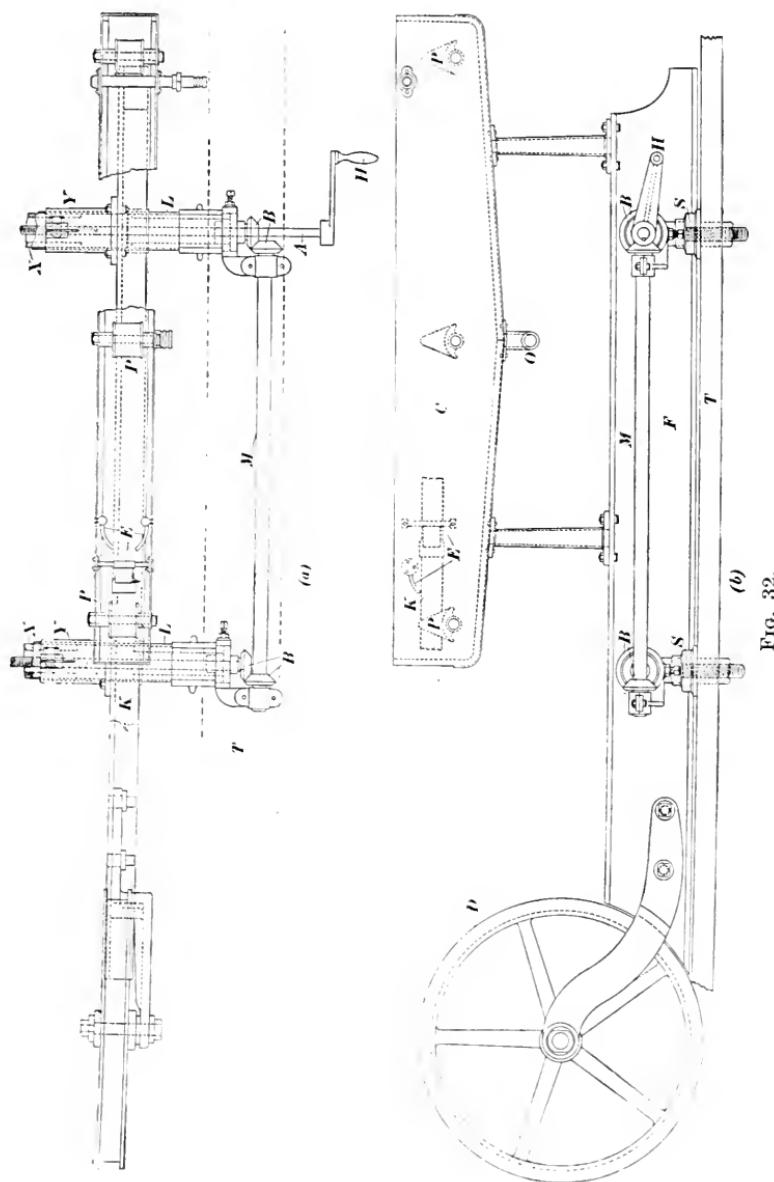
Fig. 32.

deckle frame can be moved independently, which enables the
machine tender to steer clear of a bad spot on the wire, by moving

the sheet to one side; or he can give more or less trim on one side or the other, without changing the slitters, etc. The frames carry sleeves Y, which slide on the tubes X, made in sections, the outer section being supported at the shake rails.

67. Each deckle frame supports a deckle **wash trough** C. The deckle strap K travels over the supports P, and is cleaned by the scrapers E on the top and sides, as it passes, and by streams of water playing over it; the water is led away by a pipe connected to the outlet O. The deckle pulleys D, next the breast roll, are supported by brackets that are fastened to the outside of the frames, and the apron side pieces are clamped to the frame at this end. The details just mentioned vary in different makes of machines; but, in general, they all follow the type of design here described.

Since the wire drags the deckle straps with it, the passage of the straps through the wash troughs and over the deckle pulleys should offer as little resistance as is possible. The scrapers E should be only close enough to clean the strap without holding it, and the supports P should have a smooth and easy curved surface. A strong stream of water should play on the strap wherever a scraper acts on it. If the strap be not clean, it may cause a ragged edge on the sheet, which may make it stick to a press roll and break the paper.

68. Shakeless Deckle.—If the deckle is supported on the Fourdrinier table bars (shake rails), it must **shake** with the forward end of the machine; and when the machine is large, the deckle parts are heavy and cause considerable vibration. For this reason, **shakeless deckles** have been invented, the deckle part being supported by columns from the machine foundation. However, the shakeless deckle cannot get away from the **deckle strap,** which must rest on the wire, and the wire causes the straps to shake and move to and fro while traveling from the table onto a pulley, and when passing from a pulley to the table. This shaking to and fro of the deckle straps on the wire near the deckle pulleys at the apron, will give a very uneven edge to the paper. In the case of a shakeless deckle, this effect can be overcome by clamping a strip of metal to the table bar, or to the deckle frame, in such a manner that it will hold the inside edge of the deckle strap down on the wire.

69. Deckle Pulleys.—The **deckle pulley** should be amply large; not only because less work is then required from the wire

but also because the straps will last longer. The following table, issued by a prominent manufacturer, gives the minimum diameters of deckle pulleys for different sizes of straps, and the pulley diameters should not be less than those here specified:

Thickness of strap (inches) $1\frac{1}{2}$ $1\frac{5}{8}$ $1\frac{3}{4}$ $1\frac{7}{8}$ 2 $2\frac{1}{4}$ $2\frac{1}{2}$
Diameter of pulley (inches) 16 18 20 22 24 26 28

The second pulley is usually without *crown*, is 6 or 8 inches wide, of the same diameter as the flanged pulley, and is attached to a shaft extending across the machine near the first suction box. The shaft is carried in brackets that are supported by the table bars.   Instead of a single long shaft, very wide machines have two short shafts.   The pulleys are attached to the shaft by means of set screws or clamps; if these turn on the shafts, collars are used to keep the pulleys in position.   An additional deckle strap support may be provided between the pulleys just mentioned and the wash trough.

70. The deckle-strap pulley should never be allowed to stand still while the machine is running; the deckle strap should run as freely as possible, because the wire must pull the strap.   If the pulleys are not turning, the strap is forced to slip around them; the friction between the strap and the pulley then causes the strap to drag, and this, in turn, acts as a hold-back to the wire itself.   Such a condition of affairs causes the wire to be strained on the edges, and cracks quickly begin to show themselves.   The dragging of the strap on the wire also prevents the formation of a clean, even edge on the sheet of paper.   It is not unusual to see paper machines with deckle pulleys of small diameter that are not even turning; the wires on such machines wear out much faster than they would under better operating conditions.

THE SLICES

71. Purpose of the Slice.—Fig. 33 shows a slice in plan and elevation; there may be either one or two slices to a machine. As the stock in the flow box flows to the wire between the deckles, the thickness of the stream is controlled by a cross piece, called the **slice,** which is placed between the deckle frames, near the breast roll.   The nearer the slice is to the breast roll the better; because the apron must be extended up to the slices, to insure control of the stock, and the greater the area of wire that is covered by

the apron the less is the forming surface that is available on the table. The stock that is held back by the slice is called the **pond.**

72. Slice Details.—There are usually two slices, on fine-paper machines, about 12 inches apart, which extend right across the machine. The slice or slices, as the case may be, are raised or lowered, so as to control the thickness of the stream of stock and keep the surface even. The height of the slices with respect to the wire is adjusted by means of screws N; and when the proper height is obtained, the lock nuts L keep the slices stationary. The
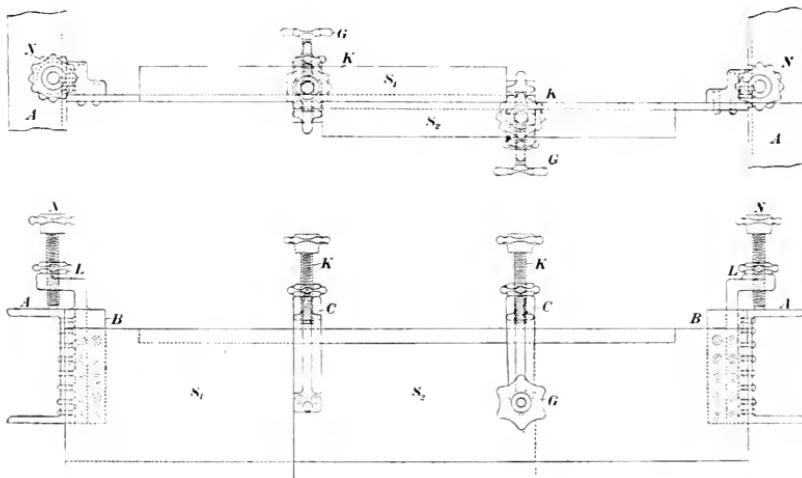
Fig. 33.

brackets B, supported and moved by the screws N, have tee(T) slots, in which tee slide bars move up and down; these tee slots are riveted to the deckle frames A. The slices are made in two parts, S_1 and S_2, to allow of sidewise adjustment; and they are joined and kept in line with each other by means of the adjusting screws K and the pinch screws G. These screws are held in clamps C, carried at the free end of either slice bar. When the deckle frames are moved in or out, as described in Art. **66,** the pinch screws are loosened, so the slices will move with the deckle frames. The pinch screws sometimes pass through horizontal slots in the slices.

73. Position and Adjustment of Slices.—Care should be taken that the lower edge of the slice is kept straight and unbruised; a rough edge will gather fibers, which will break away in bunches

and give trouble. The lower edge must be parallel to the surface of the wire, to insure a uniform thickness of stock as it flows onto the wire. Good results are obtained by placing the slices a little back of the center of, or between, the table rolls; they should never come exactly over the center, since a roll not in dynamic balance will cause streaks. The depth of the stock behind the slice controls the rate of flow of stock to the wire; this depth may be as much as 3 feet, with the slice shown in Fig. 30.

When the stock is slow and carries (retains) water well, the slice should be kept well down, especially when making fine papers. No more water should be used than is absolutely necessary to carry the fiber until it has been felted properly—the more water the more pumping. The level of the stock behind the slice should be such that the flow of stock will not be slower than the speed of the wire, when it flows onto the wire. The deeper the pond the faster, of course, will be the flow of stock onto the wire.

THE SHAKE

74. Purpose of the Shake.—The breast-roll end of the wet part is swayed to and fro continuously, which is called the **shake;** this agitates the pond behind the slices, and it also agitates the stock as it flows to the wire, which causes the fibers to felt together, as they settle with and through the water. The uniform interweaving thus obtained helps to make the paper equally strong in all directions.

75. Amount of Shake.—The vibrating motion of the breast-roll end of the Fourdrinier wire is variable, the maximum movement being about $\frac{5}{8}$ inch and the usual amount about $\frac{1}{4}$ inch. This movement is caused by the shake head and shake connecting rod. The wet end of the Fourdrinier is supported on flexible springs on rocker arms, or is hung from an overhead beam, so the breast roll and wet end of the wire can swing to and fro. The **shake head** on K, Fig. 2, is a revolving disk, with an eccentric pin, to which one end of the **shake connecting rod** is clamped; the other end of the rod, connected to the breast roll supports, transmits a wire-vibrating movement. The amount of shake can be altered by moving the eccentric pin nearer to or farther away from the center of the shake-head disk, to suit the character of the stock; and the number of revolutions per minute of the shake head can be altered by shifting the belt on cone pulley K, to which the shake head is

connected.   Many of the new machines for such papers as news-
print and the like, are made without any shake; this permits more
substantial construction, and is one less cause for worry to the
machine tender.

The interweaving of fibers by the shake is partly due to care-
fully adjusting the speed of the stock to the speed of the wire.
The most carefully felted sheets are secured when the fibers
settle by gravity as the water drains away; the fibers then fall
naturally and evenly in all directions, and there is no "dragging
the feet from under them," as it were.   The effect of the shake
is to knock the fibers down crosswise, while the forward travel
of the wire pulls them down lengthwise of the sheet.   The
shake can be varied from a long, slow motion to a short, jerky
motion; as a rule, the more violent the shake the better the
paper.

FOURDRINIER ROLLS

76. Kind of Rolls.—Before describing the Fourdrinier rolls,
attention is called to what a roll is and to its uses.   There are
many rolls across a paper machine, and they are made of various
materials, as wood, bronze, steel, cast iron, and even stone.
They all tend to sag in the middle because of their weight, even
without carrying any load on them.   In addition to their own
weight, the **table rolls** support a part of the weight of the wire
and a part of the weight of the stock from deckle to deckle.
Press-felt rolls are subjected to the pull of the felts; sometimes
there is half a lap of felt on a roll and a double pull, while some-
times there is very little lap and a consequently small pull;
sometimes the direction of the pull is upwards and sometimes it
is downwards.   The **dryer-felt rolls** have felts pulling upwards
or downwards on them.   The **lower-press rolls** have **upper-press
rolls** on top of them, and these upper-press rolls have levers and
weights on their journals, which increase the pressure of the
upper-press roll upon the lower roll.   In order that the machine
may make a uniform sheet of paper, it is advisable that the top
of a bottom roll be always *straight* as it turns over; similarly,
the upper rolls should be straight across the bottom rolls.

77. Crown of Rolls.—In order to keep the sheet of paper
uniform, it is necessary to **crown** a single roll, or the lower roll of
a pair, by making its diameter in the middle just enough larger

than at the ends to make up for the sag in the middle that is caused by the weight the roll carries when in the machine; the crown is measured in thousandths of an inch.

78. The Breast Roll.—The **breast roll** 4, Fig. 27, should not be crowned; because the wire wraps around a large part of its circumference, and if the roll were crowned, the wire will be stretched in the middle more than at the ends, thus making the center of the wire travel ahead; this would not only shorten the life of the wire but it would also tend to give an uneven surface on the table.

79. Breast Roll Details.—The fact that the breast roll is driven by the wire makes it necessary, in order to lengthen the life of the expensive wires, that this roll should turn easily.   It should be as light as possible; it should also be fairly large in diameter, so the wire may turn it more easily, and thus reduce the strain on the wire that is due to bending the wire around the roll. For a roll to revolve easily, it should be *in balance;* it should be as light as possible, yet stiff enough to keep its shape; lastly, the journals should be well lubricated.   In more modern machines of a large size, the advisability of using ball or roller bearings on some rolls of the paper machine, to reduce the strain on the clothing,[1] has become more generally recognized.

Attempts to drive the breast roll independently have not been successful, because of the practical difficulty encountered in so driving the roll that its peripheral speed will exactly equal the speed of the wire, which is driven by the lower couch roll.

Fig. 27 shows the breast roll in place, with the doctor as usually hung; the doctor scrapes off the pulp and keeps it from passing around with the roll, under the wire, and so stretching the wire and making bulges in it. For reasons previously stated, all breast rolls are ground straight, *i.e.,* without any crown.

This roll is on the wet part of the machine, and should therefore be made of non-corrosive metal; it is also in position to pick up much fiber, and should therefore have a doctor to keep it clean.   A similar line of reasoning may be applied to the other rolls of the machine.

[1] **Clothing** is the name given to the combination of wire, jacket, wet felts and dryer felts.

Fig. 34 shows a section of a breast roll; and it will be seen that every effort has been made to produce a breast roll that will be as light as possible. The extension with the brass sleeve is
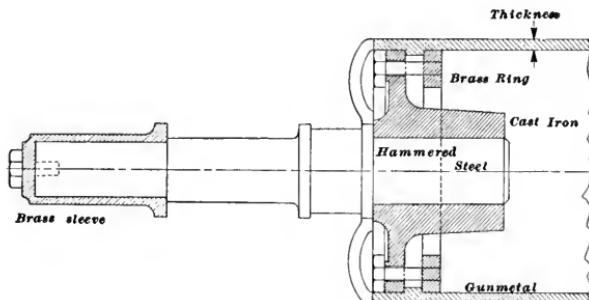
FIG. 34.

provided for the purpose of slipping the end of a *porter bar* or *lifting lever* (see Fig. 35) over the end of the journal, as the breast roll is being lifted out of the machine when changing wires.
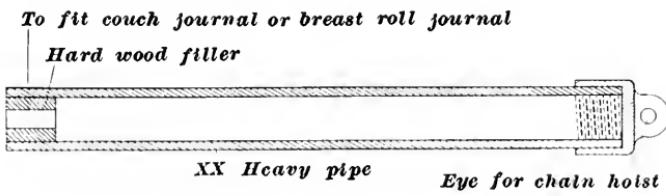
FIG. 35.

80. Table Rolls.—Fig. 36 shows a roll that consists of a steel tube, cast-iron heads, and steel journals; this type of roll, covered with a brass tube or casing, is a standard design of Fourdrinier
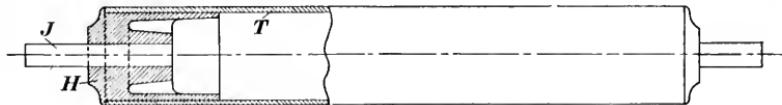
FIG. 36.

roll. The illustration shows the general construction of stretch, guide, and wire rolls.

The table rolls must be as light as possible, consistent with the securing of the necessary stiffness. They are made from a brass tube T, and have a cast-iron or brass head H, which carries the steel journal J. The journals rest in adjustable bearings that are supported by the shake rails, either on the rails or under them.

81. Size of Table Rolls.—Fourdrinier rolls will soon deteriorate if acid stock (which arises from alum or antichlor) is used. The acid soon attacks the zinc in the brass covering; and, in course of time, it leaves only a rotten, porous, copper shell, which will readily break. This action occurs in connection with all brass parts. The table rolls have the smallest diameter of any of the Fourdrinier rolls, varying from 2 inches in diameter on small machines to 6 inches or larger on the very wide machines. Machine designers now recognize the advantage of large rolls.

82. Care of Table Rolls.—Care should be taken to keep the table rolls turning; if a roll be allowed to stop turning (become dead), it wears the wire, and the roll itself wears flat where the wire passes over it. When a roll having a flat spot on it turns, it bumps the wire and makes ridges in the paper. If a roll will not keep turning after proper lubrication and adjustment, it should either be replaced with a new roll or, if only slightly worn, the journals and bearings should be inspected and corrected.

In addition to reducing the friction between the table roll and the wire, there is another reason why the table rolls must turn; the moving surface brings the water out of the paper more easily, which does not occur when the rolls are not turning.

83. Effects Produced by Table Rolls.—Because of the wearing effect produced by the friction between the rolls and the wire, some machines have been equipped with a light belt drive on
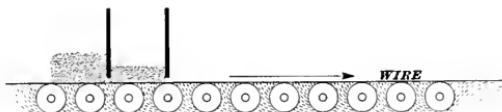
FIG. 37.

these rolls; this eliminates dead rolls. Dead rolls may also be avoided by using ball bearings. In order that the rolls may turn, it is necessary, of course, that the rolls be in contact with the wire. The diagram, Fig. 37, illustrates how the swiftly turning rolls on high-speed machines tend to throw water back under the wire. The rolls have much the same effect in inducing water to leave the under side of the wire as is produced by touching the inside of a wet tent or a string of rain drops. An English writer[1] explains the action of the table rolls by assuming that a slight vacuum

[1] CHALMERS, in *Paper Making and Its Machinery*, 1920, p. 78.

tends to form in front of the roll. A film of water may follow the roll to the wire and flow down the back side of the roll. A discussion of the dynamics of rolls is given in Art. **214.**

84. Effects of Water and Its Removal.—It is necessary to have sufficient water in the stock to keep the fibers in suspension for a considerable distance on the wire; this affords time for the fibers to interweave properly and to produce a well-formed sheet. Since water drains rapidly from a free stock, such as is used for coarse papers, more water is used to produce this degree of suspension. High-grade papers are made from slow stock, and the amount of water required is less in this case. Most of this water is removed as the paper passes the table rolls, and it is here that the paper is formed.

The forming table and the suction boxes must take out enough water to keep the paper from being **crushed** at the couch press, which is the effect produced when the water is pushed out unevenly, leaving the fiber in blotches. With stock of the same freeness, the more table rolls the faster the machine can be run. If the paper be too wet at the first suction box, the machine should be slowed down, less white water should be added at the regulating box, or the stock should be made more free. To make the stock more free, warm the stock as it comes to the machine, or, better, change the treatment in the beater; heating costs money. If the forming table takes out the water too quickly, the instructions just given may be reversed, or several of the roll bearings may be lowered until these rolls are out of action, out of contact with the wire. Adjacent rolls should not be lowered nor those toward the suction boxes.

When making tissue papers, the table rolls should be close enough together to keep the water that has been removed from being thrown back against the under side of the paper; a thin paper, such as cigarette paper, will be spoiled if drops are thrown against the under side of the wire. When starting a fast machine on coarse paper, it is well to begin with plenty of water, cutting it down if necessary; the opposite procedure should be followed in the case of a slow machine on fine papers.

SUCTION BOXES

85. Purpose and Description.—The **suction boxes** must take out sufficient water to keep the paper from being crushed under

the couch press. The usual design of a suction box is shown in Fig. 38. The box is made of bronze, and its interior is rectangular in shape. The bottom of the box is connected to the suction pump by means of a pipe 3; in some designs there are as many as six outlets from the box to this pipe. The rubber pistons 1 are pushed in or are pulled out by means of the handles 2, the ends of which fit into slots in the pistons and lock them in position. The pistons are set just under the edge of the paper, to keep air from entering the box. On the top of the box rests a perforated cover 4, made of hardwood—maple or mahogany—or, sometimes, of hard rubber or brass; maple is preferable for suction boxes, since it can be easily planed and kept smooth; and the cover must be kept smooth, to reduce the friction as the wire passes over it. The wire wears ridges or grooves in the covers, which soon destroy the mesh or cause the wire to wrinkle and produce defects in the paper; the covers should, therefore, be planed smooth every week end. If the stock be coarse and but little suction required, it is bad practice to close one box entirely; it is better to decrease the suction on *all* the boxes, by slightly closing the valves on the vacuum pump suction.

From 4 to 9 boxes are used, according to the kind of paper, speed of the machine, and the amount of water left in the stock after passing the table rolls. Some machines are equipped with a device for giving a reciprocating motion to one end or both ends of the suction boxes (all connected together), so as to minimize the scoring of the box tops. A great deal of work has recently been done on the subject of suction boxes, and successful new designs will doubtless soon be in use.

86. Amount of Vacuum.—A vacuum gauge should be placed on the suction-pump line from the suction boxes, so the machine tender can be guided in his control of the suction. From 7 to 10 inches of mercury (vacuum) is ample for the suction; and if the work of the boxes is not satisfactory when over 7

Fig. 38.

inches of vacuum is shown on the gauge, it is better to place an additional box under the wire than to strain the wire too much by increasing the vacuum to above 10 inches. It is not unusual to see 14 inches of vacuum on suction boxes; but this is bad practice, as the wires are then soon worn out. The suction pulls the wires down onto the top of the boxes and tends to make the wire drag, like a brake. A vacuum of 7 inches on a 100-inch machine is equivalent to a load of about 1000 pounds for each box; this not only increases the pull required to drag the wire off the boxes but it also causes a suck in and release as the wire passes, which strains the mesh. In a patented arrangement, this effect is minimized by placing the boxes contiguous. As previously stated, these strains on the wire should be made as small as possible, so as to save the wires and make good paper.
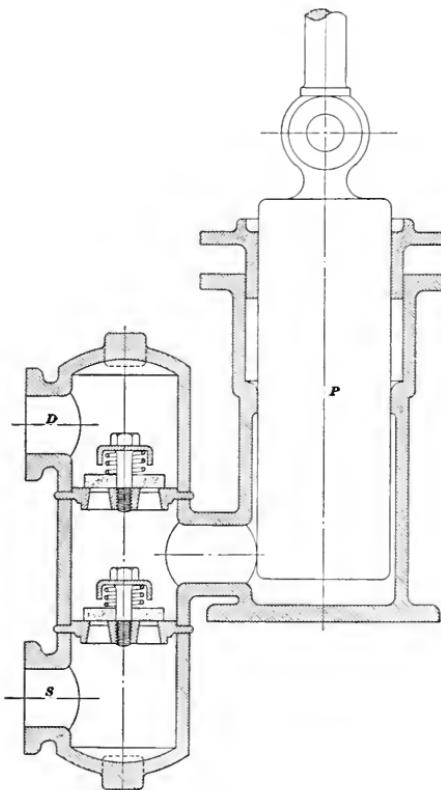
87. Suction Pumps.— The suction pump is often similar in design to the stuff pump, but the valves must act quickly. Fig. 39 shows a section of one cylinder of a suction pump, which may have two or three cylinders. The suction-pipe connection S is connected to the pipe 3, Fig. 38, of the suction boxes. Between it and the pump is a separator for taking out the air that is drawn through the paper as the water is removed. This water contains recoverable fiber. The discharge pipe D delivers the water and fiber, sucked from the suction boxes, into save-alls or to the sewer. The action of the disk springs, as the plunger moves, is the same as that of the ball valves of the stuff pump shown in Fig. 5; the spring insures quick and positive

Fig. 39.

closing, with minimum leakage. In Fig. 39, the plunger P has just finished a down stroke; the air in the pump has been expelled through D, and the lower valve is about to open, as the up stroke of P admits air through S. The cushioning effect of the air is so materially reduced by the vacuum created that the seating of a valve is much more sudden than it would be if it were moving in the atmosphere; this necessitates moving parts of special design. Rubber is generally used in the manufacture of the suction and discharge valves; but experience has shown that rubber-ball valves are not as good as rubber disks, with controlling springs.

88. Displacement of Suction Pumps.—The displacement of the suction pump should approximate 500 cu. in. per inch of width of wire and for each 100 feet of paper made per minute. Hence, for a width of 130 in. and a speed of 450 ft. per min., the displacement under these conditions should be $500 \times 130 \times \dfrac{450}{100}$ = 292,500 cu. in. per min. However, this amount is possibly excessive, if applied to high-speed news-machine problems, when the speed is over 600 ft. per min.; the paper then loses its moisture, and the work required of the pump is less in the last suction boxes than in the first boxes. While the paper machines may have a varying number of suction boxes for the same speed, the greater part of the work done by the pumps is in the first two or three boxes; therefore, the same displacement of pump will, as a rule, take care of an extra suction box, if the displacement be calculated according to the above rule. The character of the stock governs to a certain extent the amount of suction required; for instance, groundwood is slower stock than sulphite, and thus requires a higher vacuum to suck the water out. But when the stock is slow, the machine is usually slowed down.

On a suction couch roll, a higher vacuum is necessary in order to do efficient work; this is also true of the wet-press suction boxes. The size of the pump for press suction boxes can be taken care of by allowing 275 cu. in. displacement of suction pump per minute per inch of width of press roll. In order to exert a continuous suction on the wire or press felt, the smallest capacity of pump that is practicable is 6″ × 8″, that is, 6 in. in diameter by 8 in. stroke.

Other types of exhausters, especially centrifugal pumps, are also used on suction boxes instead of the displacement pumps
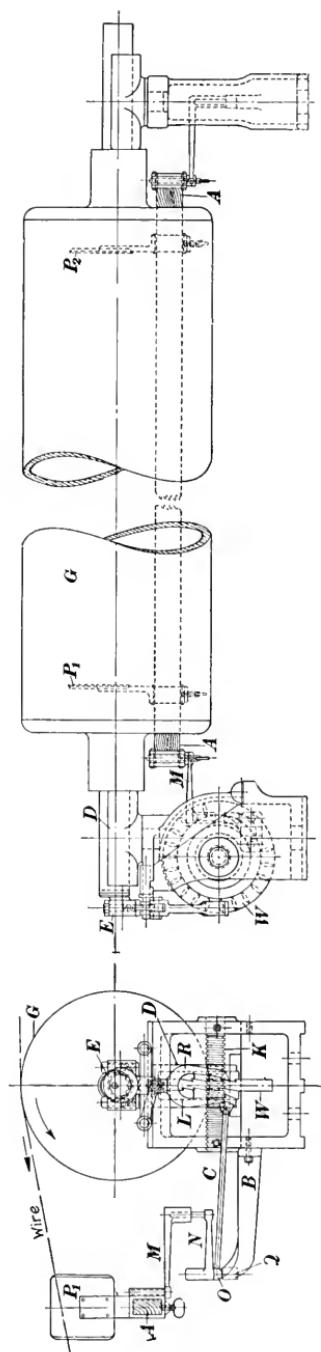
here described; these other designs are at least equally efficient. A special treatment of the subject of pumps is included in Vol. V, in the Section on *General Mill Equipment*.

GUIDING THE WIRE

89. The Guide Rolls.—The **guide roll** 8, Fig. 27, is provided with a wire guide on the front side of the machine. A design of wire guide, as attached to the guide roll on a left-hand machine, is illustrated in Fig. 40. The guide acts by shifting the position of the bearings, carrying the front end of the roll forwards or backwards as the wire gets out of line.

90. The Palms.—Referring to Fig. 40, two **palms**, or **fenders**, P_1 and P_2, are fixed on a wooden rod A, which crosses the machine under the wire in such a manner that the edges of the wire just clear the palms. Now consider what happens when the wire travels to the front side[1] and pushes against palm P_1. This action moves the wooden rod A to the front of the machine, carrying with it link M, which is firmly keyed to rod A; and this, in turn, moves bell-crank levers N and O. The latter revolves

[1] The **front side** of the machine is the tending side, the side opposite the one on which the drive is located, which is called the **back side**. Hence, on a left-hand machine, the front side will be on the right, when looking toward the wet end (see Art. **54**).

Fig. 40.

around the center pin Q, which is carried by bracket B. One end of lever O is connected to rod C, which, as the front palm comes forward, pulls the double pawl L and R, so that pawl R locks into the rachet wheel W. Since the double pawl is hung on the eccentric E, it moves up and down once with every revolution of the guide roll, and it is constrained to move vertically. When, as in this case, the rod C pulls pawl R, which is in gear with the wheel, the pawl pushes down on the wheel, turns it around, and causes it to travel to the *right* on screw K, toward the direction in which the wire is traveling. Since the ratchet wheel carries the front bearing D of the guide roll, the result of the above described movements is to screw the front side of the guide roll forwards by means of its own revolutions, thus causing the wire to be forced by the guide roll to travel back again to its normal position.

If the wire tend to travel toward the back, or driving, side of the machine, the movements above described are reversed; pawl L then locks into the ratchet wheel, *lifts* on the ratchet wheel, and causes it to travel to the *left*. The new position of the roll causes the wire to retrace its path toward the front of the machine.

There are other types of wire guides, but they all work on the same general principle—that of shifting the front bearing of the guide roll. A widely used type has but one palm, held against the wire by a spring; it is especially adapted to wide machines. A new type has no palm; a water jet which strikes a spoon lever if the wire moves either way, actuating the gear.

THE DANDY ROLL

91. The Watermark.—When it is desired to make a **watermark** (a name or design) on the paper, it is effected by using a dandy roll. A **dandy roll** is a skeleton roll, covered with wire cloth, upon which the design is worked in fine wire, though brass letters are sometimes used. This raised design makes the soft paper thinner where it comes in contact with the design, and the outline shows clearly when the paper is held between the eye and the light.

92. Wove and Laid Papers.—If the paper is to be alike on both sides and without a watermark, the dandy roll is covered with fine wire, similar in texture to the machine wire. This dandy roll produces what is called **wove paper;** because the wire impressions are similar on both sides, and the paper has the appear-

ance of being woven. A dandy roll that has a series of wires on its surface, the wires being so arranged as to produce *parallel* lines on the paper, these lines being more transparent than the rest of the paper, produces what is called **laid paper.**

93. Size and Position of Dandy Rolls.—The diameter of a dandy roll varies from 7 to 24 inches, depending on the width and speed of the machine, the design of the watermark, and the kind of stock; it is placed on the wire and between the suction boxes, see 7, Fig. 27. The roll rests on the wire, and its journals revolve in guides rather than in bearings. The roll is turned by the friction between it and the paper. As this roll runs on the surface of the paper, it presses out some water, and it gives the paper a closer and finer finish, which is its primary function.
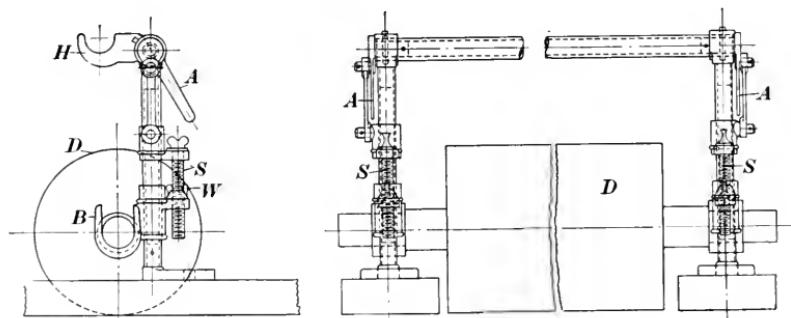
Fig. 41.

The circumference of a dandy roll is usually a little less than the distance (lengthwise) desired between the watermarks on the dried sheet; this allows for *stretch.* The distance crosswise between the designs is a little greater than is desired in the dried sheet; this allows for *shrinkage.* Dandy rolls for loft-dried papers should have a greater width between designs, because of the greater shrinkage in high-grade papers.

94. Fig. 41 shows a design of dandy-roll stand, and by referring to Fig. 27, the usual position of the dandy roll will be noted; it is generally placed after the first set of suction boxes, but not directly over a roll. Fig. 41 shows the adjusting screws S, with a thumb head, and wing nut W, for adjusting the height of the dandy-roll guides B to accord with the size of the dandy roll D. Lever A is so linked to the dandy-roll guides or bearings that an upward movement of the lever will immediately lift the dandy roll from the surface of the paper, if, for any reason, it is necessary to do

so. When not in use, as when starting the machine, the dandy roll may be hung in bracket *H*.

When the dandy roll makes proper contact with the paper, a wet streak of even width shows just behind the roll. Experience is required to get the right amount of wetness to the paper, so the dandy roll will make the right impression. This is done by controlling the suction and by proper beating of the stock. The paper in this book is made with a wove dandy. A *surface mark* is obtained on some machines by printing the letters on the paper as it passes over one of the hard rolls of the press part.

95. Defects Caused by Dandy Rolls.—Dandy marks sometimes cause defective paper and breaks. The wire cloth that covers the skeleton drum may become plugged in the meshes with fine particles of stock and filler; and when this occurs, the water on top of the sheet cannot penetrate through the plugged meshes. As a consequence, the sheet at these points tends to stick to the face of the dandy roll, and it is slightly lifted by the roll. This action causes a mark on the sheet that has somewhat the shape of a half moon, and there is only one remedy for it: the dandy roll must be taken from the machine and thoroughly washed out with water and steam. When the meshes are badly plugged, and the plugs are dried into the wire cloth, it may be necessary to use a steam hose. In some cases, dilute oil of vitriol (sulphuric acid), lightly applied with a cloth, is necessary to clear the dandy roll of these obstructions, and some mills keep steam or air jets blowing through the dandy on the machine. A piece of wet felt, tacked to a bar, may be hung the length of the dandy for use as a wiper.

Unless very carefully cleaned at the end of a run, some paper stock will adhere to the wire, and the acid treatment will be required when the dandy is next used. The acid wash is prepared by pouring sulphuric acid into a pail of water until a distinct acid taste is noticed, about like lemon juice. The roll is placed on two supports (little horses); it is then scrubbed carefully, and is washed thoroughly with a hose. Pour the acid into the water; it is dangerous to pour water into the acid.

96. Putting On and Removing Dandy Rolls.—To put on a dandy, the machine tender holds it vertical; then, with the journal in one hand, he makes a fulcrum of the other hand, about 2 feet from the lower end, rests his elbow on the shake rail, and gradually lowers the upper end. His back tender stands on the

back shake rail, catches the back end, and fits the journal to its
bearing.   The machine tender gives the roll a slight twirl in the
direction of the paper travel as he drops the roll quickly and gently
on the sheet; this can be done without breaking the sheet.

To remove the dandy, the back tender and the machine tender
stand as before, and they quickly lift the roll from the paper.   The
back tender gives his end a quick strong lift, but not too strong,
and the machine tender brings the roll to an upright position,
where he can balance it; he generally gets a good wetting from the
water in the roll.   Wide machines have a plank walk across the
wire, supported from the frames, so the roll way be carried off.

COUCH ROLLS

97. Purpose of Couch Rolls.—The function of the **couch** (pro-
nounced *cooch*) **rolls** is to remove water from the formed paper
and pack the fibers firmly together, so that the sheet is strong
enough to pass to the first press.   The top couch roll is couched
toward the wet end; that is, it is not directly over the center of
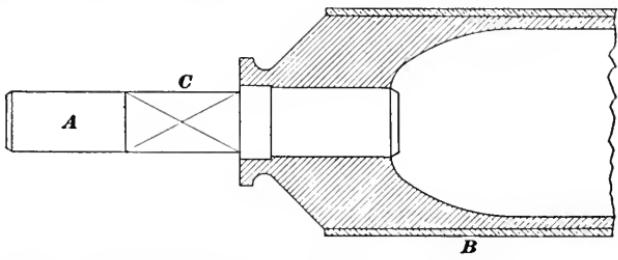
| Width of Machine | 100″ | 125″ | 150″ | 175″ | 200″ |
| Diameter of Roll | 20″ | 24″ | 26″ | 28″ | 30″ |

Fig. 42.

the lower couch roll, see Fig. 27, but bears somewhat on the wire,
which acts as a couch.   This arrangement permits water to be
pressed out, and it causes the paper to be gradually squeezed
between the wire and the felt jacket on the upper roll before being
finally squeezed between the two rolls.   The couching action
guards against crushing the paper, which occurs if the sheet be
too full of water when entering the "nip" between the two rolls;
and the water has a better chance to get away when squeezed
through the wire.

98. The Lower Couch Roll.—A section through a lower couch
roll is shown in Fig. 42.   The extension A provides room for the

lifting pipe or porter bar, Fig. 35, to fit over; C is the journal, and B is a shell, made of bronze, gun metal, or brass. This is a driving roll, with a heavy load to carry; it is exposed to moisture, and must not be crowned. A comparison of Figs. 42 and 34 shows that the couch roll is more solidly designed than the breast roll.

As is the case with the breast roll, the lower couch roll is not crowned because an increase in the diameter at the middle of the roll would tend to stretch the wire or would, in any case, make it travel faster at the center, which would cause strains and partially close the mesh. In most cases, the lower couch roll is covered with a brass or gun-metal shell.

99. Driving the Couch Rolls.—The lower couch roll is driven, and it pulls the wire over the other rolls and the suction boxes—a heavy load. The tendency of the wire to slip on a smooth roll is sometimes counteracted by covering the roll with rubber. A grooved roll is sometimes used on light papers, and a felt-jacket covered roll may be necessary to prevent the wire from marking the paper, the weight of the upper roll pinching the paper against the wire and the lower roll, thus impressing the mesh of the wire in the soft sheet.

In spite of all attempts to devise a mechanical drive—by means of a slipping belt, etc.—the upper couch roll may be considered as driven indirectly from the lower roll; the lower roll drives the wire, the wire carries the soft sheet of paper, and the paper really drives the upper couch roll. The nature of this sheet of paper demands that very careful attention be given to the condition of the bearings, to lubrication, and to the setting of the upper roll with reference to the lower roll, both as regards their position and the pressure between the two rolls.

100. Crushing—Cause and Remedy.—Adjustment of the pressure between the couch rolls requires consideration of the wetness of the sheet, to prevent crushing of the sheet. **Crushing** is a blotchy or curdy appearance of paper; it is caused by a too rapid pressing out of water, which pushes the fibers into bunches.

Crushing is common with heavy papers, the fiber of which may pile up before the roll, like sand in front of a small wheel. The remedy is to increase the freeness of the stock, using less water (which may, however, interfere with good formation), putting more table rolls into commission, increasing the suction on the

suction boxes, and relieving the pressure on the upper couch roll; it may also be overcome by using a suction couch roll.

101. Couch-Roll Housings.—The two bearings of the upper roll are carried by the swinging arms of **couch housings,** see Fig. 43, which shows diagrammatically two typical designs. View (a) shows a bevel pinion on shaft S, which is actuated by a hand wheel (not shown); this pinion turns the larger gear A, which acts as a rotary nut and pushes or pulls on the screw B, thus

Standard Couch Bell Crank Housing

(a)

Worm and Wheel Bell Crank Housing

(b)
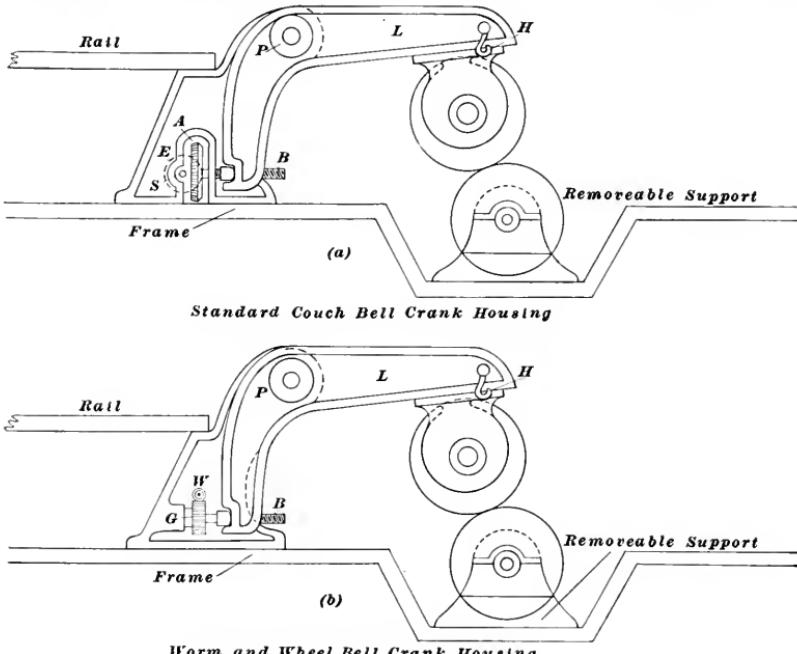
Fig. 43.

moving the coucher arm L around the pivot pin P. Fig. 43 (b) shows a worm and worm wheel instead of a bevel and pinion. The worm W is actuated by a hand wheel (not shown); it turns the wheel G, which acts in the same manner as the larger bevel gear A, in view (a).

The design shown in view (a) is suited to fairly narrow machines, while that shown in view (b) is for wider-faced and heavier upper couch rolls on wider machines, the worm-and-wheel gearing giving a larger lifting effect than the bevel gears. It would appear to be well worth while to consider the use of small motors for furnishing the motive power to lift couch rolls,

move stretcher rolls, and to shift belts on the extremely wide
paper machines now being built.

Referring to Fig. 43, all upper arms are provided with weights
and levers, attached to hook H, for controlling the pressure
between the rolls across the machine.   As will be explained
later, in describing the press part, this design is similar in all
practical details to that used for any press, whether for a couch
roll or for any press part situated farther up the machine.
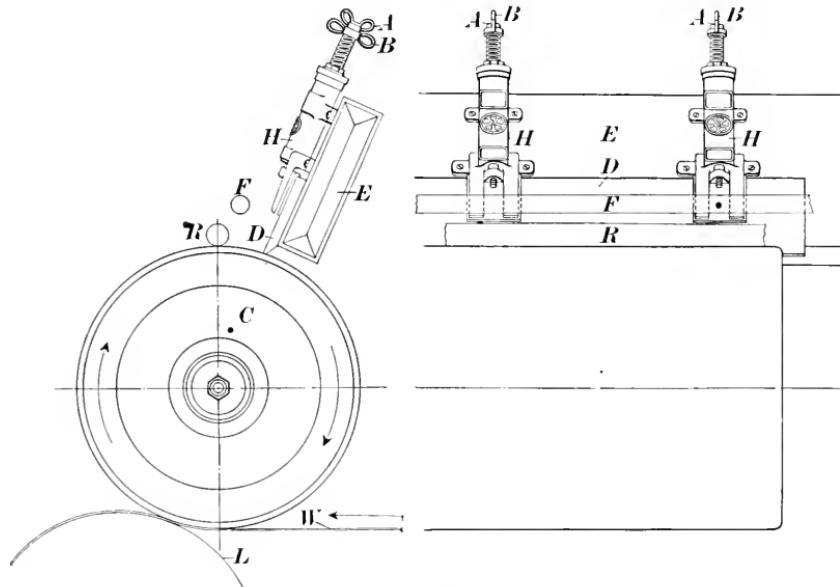
FIG. 44.

The upper couch roll is covered with a felt jacket, to secure a
dry sponge effect on the wet paper; it is a descendant of the
traveling upper felt E, Fig. 26.   Further information concerning
the use of the couch roll and the jacket will be found in Arts.
117–122 and **141–146.**

102. The Guard Board.—The **guard board** is so placed that it
squeezes out of the jacket much of the water that has been
absorbed from the paper, and it scrapes off lumps of pulp that
might go around and dent the wire.   With the water is a certain
amount of filler and fiber, which is washed out at the ends of the
roll by the shower pipe, shown on the press side of the guard board
in Fig. 27, and at F in Fig. 44.   The guard board is set behind
the center of the couch roll; this makes a little trough, which may
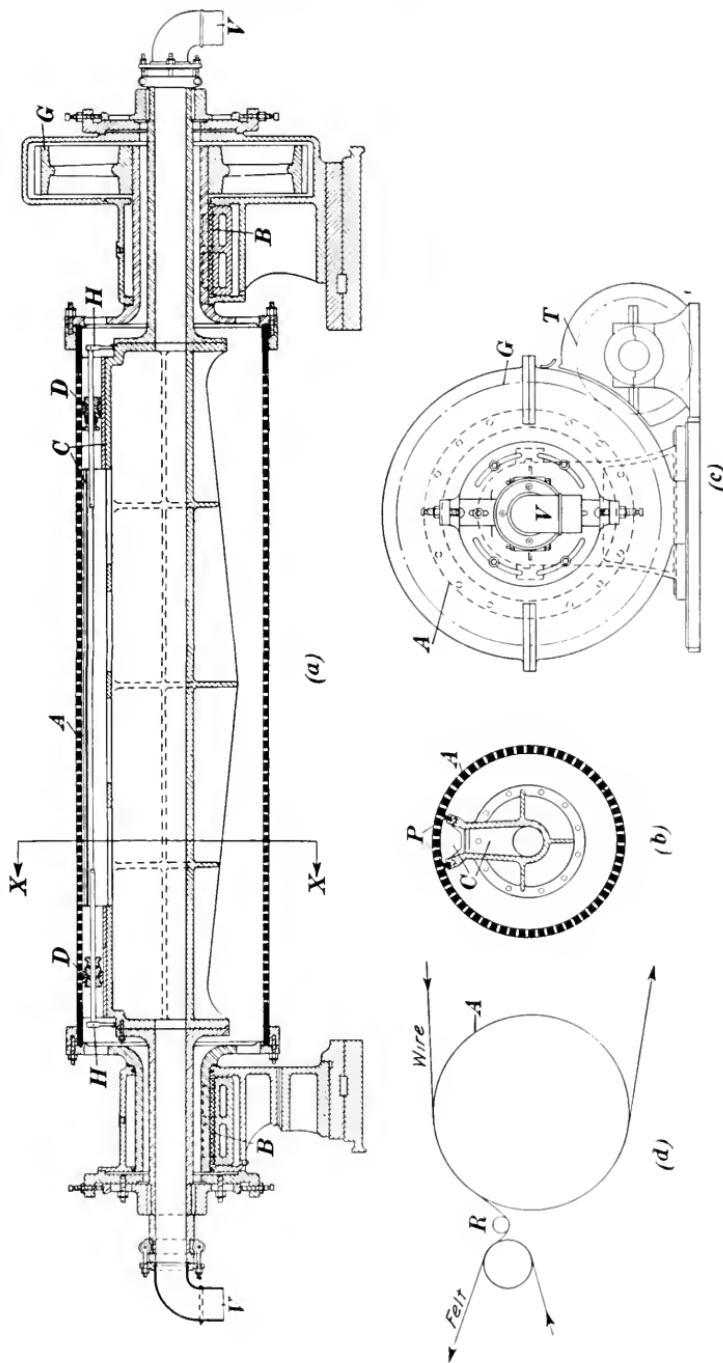
Fig. 45.

be increased by a small roll R or by a felt wiper.   Pipe F and roll R may be supported from the couch-roll housing.

The guard board should be adjustable, and it should have a flexible edge that can be adjusted to give a uniform pressure over the width of the jacket.   Fig. 44 shows a typical guard board.   A plank E is supported by cast-iron brackets, which are bolted to the top of the bell-crank arm of the housing.   On the front of this plank, the light guard-board blade D, made of maple, is held in place by a series of spring boxes H; through these boxes, double thumb screws pass, which are operated from above. If a part of the jacket is running wet, a turn of the upper thumb screw B, which operates on one of the springs, gives additional pressure to the blade; if the jacket is running dry, a turn of the lower thumb screw A serves in like manner to relieve the pressure of the blade.   Saw cuts in the upper edge of the blade increase its pliability.   Since the guard board acts like a brake, a gentler pressure on it reduces the power required to drive the Fourdrinier, and it lengthens the life of the upper couch-roll jacket and of the wire.   Perforating the shell of this upper couch roll facilitates removal of water from the jacket.

SUCTION ROLLS

103. Suction Couch Roll.—Many machines are equipped with a **suction couch roll,** and some have a **suction press roll** also; the former supplants the conventional top and bottom couch rolls, and the latter supplants the bottom roll of a pair of press rolls. In principle, a partial vacuum is created in the roll, and atmospheric pressure, instead of roll pressure, packs the fibers and squeezes water from the paper.   Many advantages are claimed for these suction rolls, and they have affected, to some degree, the design of the newer paper machines.

104. Construction and Installation.—The construction of the suction couch roll, and the method of its installation, is shown in Fig. 45.   Here (a) is a longitudinal section, (b) is a cross section on the line XX, (c) is a right end-view, and (d) is a diagram showing wire and felt.   A perforated bronze shell A is mounted in substantial bearings B; the diameter and thickness of the shell depend on the width, speed, and drag of the wire, and the best of machine-shop work is required.   The shell is revolved at the speed that is proper to drive the wire. C is the stationary

suction chamber; it is connected to a powerful rotary vacuum pump, which is driven from a constant-speed line shaft. The pump is connected at V, and is usually located in the basement. Contact between the suction chamber and the inside surface of the revolving shell is made with special packing, which is held in place by springs, or water, or compressed air. A piston arrangement D, operated by shaft and handle H, is provided on the roll, to adjust the length of the suction area to accommodate any width of sheet made on the machine. This piston fulfills the same purpose as the pistons 1 in Fig. 38. The chamber C need not be vertical, it may be swung back or forward. In view (d), the small roll R is a light aluminum roll, which is sometimes used to help maintain the proper draw of the sheet between the suction couch roll and the first wet felt.

105. Amount of Vacuum.—The degree of vacuum that can be maintained in the suction couch roll depends largely upon the weight and character of the paper made; about 15 inches of mercury is a fair average, being least on free stock and on thin paper. The shell A is driven by gear G from pinion T, shown in end view (c). It is to be noted that a suction couch roll requires more power for its operation than the ordinary pair of rolls. Since the shell is perforated, the ordinary strength formulas do not apply when designing these rolls.

106. Operation of Suction Rolls.—In order to understand the operation of the suction rolls, it must be borne in mind that after the web of paper has been formed on the Fourdrinier wire, the essential remaining problem, insofar as the paper machine itself is concerned, is largely one of removing the water that is in the sheet; and this is accomplished by the suction boxes, the pressure of the couch and press rolls, and by evaporation. There are different ways in which the necessary pressure may be applied at the wet end. With present-day, relatively high, operating speeds, the water must be eliminated very rapidly from the newly formed and tender sheet; yet, if this be done violently, the finish and strength of the paper suffer, to say nothing of the breaks that follow.

107. How the Pressure Acts.—In the case of the conventional couch and press rolls, most of the pressure is exerted on the line of contact of the top and bottom rolls. This line of contact is,

of necessity, very narrow; and since the resulting pressure is tremendous, per unit of contact area, the water is violently forced from the web of paper as it passes between the rolls. Some deranging of the fibers, or a partial breaking down of the fibrous structure that has been so carefully built up in the forming of the sheet, can scarcely be avoided with such pressing.

With suction rolls, line pressure is replaced by atmospheric pressure, which is both constant and uniform, and is applied to a controllable unit of area on the moist paper. Instead of a great pressure on a narrow contact, there is, with the suction roll, a lighter and milder pressure, which is distributed over a greater area.

108. Manner in Which Suction Roll Acts.—The suction couch roll eliminates entirely the necessity of the old top couch roll, with its felt jacket and guard board, both of which require considerable attention, and which are responsible directly for many of the troubles of the machine tender, such as crushing, pitch spots, wire marking, pick-ups, and accidents to wires. The avoidance of these troubles means greater production.

The suction-couch roll does not displace the regular flat suction boxes on the wire; but the suction can usually be kept less, thus putting a smaller strain on the wire and giving it a longer life. Damp streaks are avoided, since the atmospheric pressure is uniform; the wires glide easily and run longer; and clearer water-marks are possible, when no top-couch roll is used.

Suction rolls are in operation in machines running at speeds up to and above 1000 ft. per min., and the variation in the weight of papers being made is from 8 to 300 pounds.

109. Manner in Which Paper Should Be Taken off the Wire.—When starting the machine and taking the paper off the wire, it is very important that the sheet be picked off the wire below the suction area. The paper will leave the wire more freely when using the suction couch roll than with the old couch rolls, provided it be taken off low enough to avoid the effect of suction. The wire must not be struck hard when picking up the ribbon (Art. **52**). In several cases, wires have been ruined in this way, or when trying to pick the sheet off the suction area.

On light-weight sheets and on machines operating at high speeds, it is convenient to make use of a patented compressed-air nozzle, to blow the ribbon from the wire onto the first felt. If

unusual difficulty be experienced with the draw, it can usually
be traced to the felt suction box; for which reason, this box should
be equipped with a vacuum regulator that can be weighted to
change the degree of vacuum carried. As the vacuum increases,
the paper will run down where it leaves the wire; and as the
vacuum decreases, the draw tightens; because the felt runs slower
or faster, respectively. In some installations, the regulation of
the felt suction box is so close that the additional removal of an
ordinary $\frac{3}{4}$-inch washer, used as a weight on the vacuum regulator
valve, will change the draw of the paper perceptibly. If no
draw roll, as R in Fig. 45(d), is used, and the sheet is drawn too
tight between the wire and the felt, the sheet will be spotted;
and if it be allowed to run too slow, it will give trouble on
the felt.

The pistons D, Fig. 45, should be carefully adjusted to the
width of the wet sheet. If the pistons are not out far enough,
the edges of the sheet will run wet, and the sheet is apt to wrinkle
on the felt. Sometimes the edges will give a little trouble, if the
deckle straps are worn and leaky; in such cases, either re-grind
the deckle strap or make use of a squirt on either side of the
sheet, to cut away the fringed edges. If the pistons are put too
far out, there will, of course, be an unnecessary reduction in the
vacuum, because of the extra air being admitted.

110. Effect of, and Prevention of, Lumps.— When the suction
couch roll is used without a suction roll on the first press, lumps
(if they occur on the sheet) may cause a breakdown at the first
press roll. The proper remedy is to get rid of the lumps, which
are usually caused by dirty screens that are in need of repair.
If the cause of the lumps cannot be determined, a rubber dandy
roll may be run on top of the sheet, over the suction couch roll.
This is a soft rubber-covered roll, of small diameter, and only
heavy enough to squeeze the surplus water out of such lumps; it
also has the tendency to close up the sheet and produce a higher
vacuum. Some kinds of paper will not stand for its use, however;
and it is not recommended, except in special cases.

If the machine is not already so equipped, the addition of a
flat suction box on the first felt will help to lay the paper flat on
the first felt, and it will help to regulate the draw, as previously
explained.

THE STRETCH ROLL

111. Varying the Tension of the Wire.—Fig. 27 shows a stretch roll 12 on the inside of the wire, which is provided with a hand-operated screw, so the stretch roll can be moved up or down, in a vertical direction, according to whether the wire tension is to be decreased or increased. It is not necessary that a Fourdrinier wire be very tight; the pull of the couch roll on the wire, which drives all the table rolls and the breast roll, will keep the forming-table part of the wire tight, even if the return of the wire be loose. When using the stretch roll, the machine tender can actually pull a wire apart, if he is not careful, and he may easily put an undue strain on it. It is best to order the wire long enough to permit the stretch roll to rest in a loop.

112. Stretching of the Wire.—If the wire runs nearly straight across the stretch roll from the neighboring rolls, it is much more likely to be overstretched, without realizing it, than when the stretch roll lies in more of a loop. The tension of the wire due to the stretch roll only should not exceed 3 pounds per inch of face of the wire, and this tension should not be increased or decreased as the wire grows older. If, because of wear and tear due to being in service, the tension of a wire be altered, the joints of the mesh will loosen and begin to work; and the wire will then shear itself into cracks much more quickly than if the original tension had been maintained. The wire of the Fourdrinier will naturally get a little longer as it gets older, largely because of the pull and the friction of the suction boxes. The increase in length of a wire may be taken care of by a proper use of the stretch roll, without increasing the tension of the wire. The stretch roll should be used very carefully, in order not to put excessive tension on the wire.

ELEVATING THE FOURDRINIER WIRE

113. Elevating Device.—Fig. 27 shows an elevating device that is often used on high-speed news machines; different makers use different devices. The object sought is to give the wire such a pitch that the stock emerging from the slice or flow box will travel down grade, and at about the same speed as the wire is traveling; this results in far better formation and more uniform quality. It will be seen that the beams K, hung on either side

of the machine, carry the table bars 13, table rolls 5, and breast roll 4, and also the deckle parts. The save-all boxes are also supported on the beams K. The hand wheel W shown at the flow box is on a shaft that carries two worms, which actuate a big worm wheel on either side of the machine. These worm wheels are keyed to vertical shafts, which have screws cut on the bottom ends, the screw threads being above the end bearings in which these vertical shafts turn. These screws turn in nuts, which are a part of the flow-box ends of the supporting beams K. As the vertical shafts are turned by the operator at the hand wheel, the nuts on the ends of the beams K travel up or down, lifting or lowering the flow box, the breast roll, and the wet end of the Fourdrinier.

In wide machines, the elevating devices, which are similar to that just described, are operated by a small motor instead of by a hand wheel. The majority of paper machines are so designed that the breast roll can be raised or lowered 2 or 3 inches above or below the level of the couch roll. High-speed news machines are now often built with a permanent pitch of 18 inches or more to the wire.

MANAGEMENT OF THE FOURDRINIER PART

HOW TO PUT ON A NEW WIRE

114. Removing the Old Wire.—One of the most important tasks of the machine crew is that of putting on a new wire. When changing wires, first see that there is no danger of any roll falling out of its bearings; then make two short cuts in the old wire, about an inch apart and close to the couch roll; put in the clutch, and run the cut part onto the lower couch roll, past the nip; after which, stop the wire. Take the inch-wide strip that has been started by the two cuts, and tear it off right across the machine; put in the clutch, and roll the wire onto a wood core until the roll is large enough to lie between the lower couch roll and the first press-felt roll; then start up the wet felt, and roll the old wire up between the first press-felt roll and the coucher (couch roll). The roll is started with the core lying on the top of the wire. The old wire should be preserved; it is valuable.

The machine tender then takes off the slices and folds back the apron; when possible, lift the deckle frames and slices com-

pletely off the machine.   The crew should now take out the
suction boxes and table rolls, laying them on the tending floor,
in such order, that each part will be returned to the same place
or to its own bearings, when the new wire is put in.   All these
parts should be well cleaned and scrubbed, to remove any clay or
pulp.

Next remove the save-all boxes and the wire-carrying rolls;
the latter are usually lifted out, they may be slid out on planks,
in the case of wide machines and heavy rolls.   Lastly, remove the
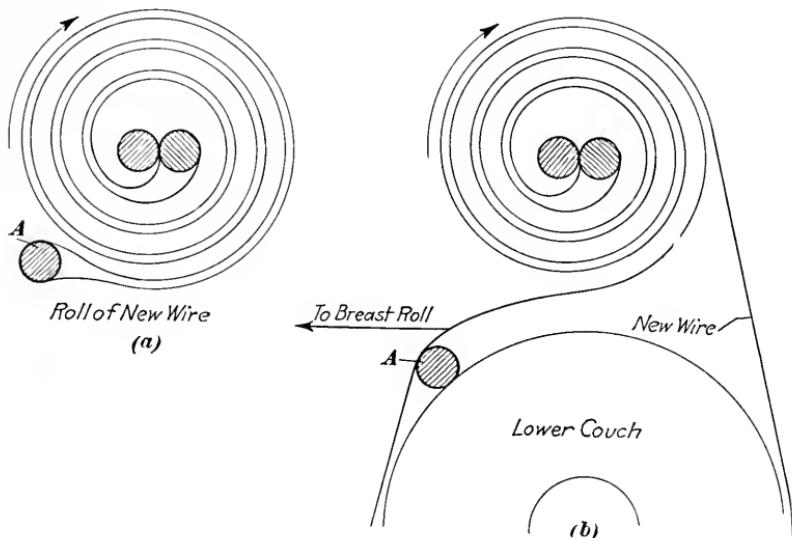
Fig. 46.

breast roll, by means of the rails and light trucks, upon which the
roll is lifted with the chain hoist.   Now send for the new wire, and
have the millwright plane the suction-box covers.   The upper
couch roll is lifted by means of the bell cranks and gear, and the
cap of the lower roll bearing is removed.

The porter bar is placed in the wire by putting it on the end of
the wood spar A, Fig. 46(a), which is in the wire when purchased
and received.   As this spar is pushed out, carefully follow it
with the porter bar.   When the spar has thus been replaced with
the porter bar, one end of the bar, Fig. 35, is placed securely over
the extension of the lower couch journal, and the other end is
lifted by a chain fall (block and tackle) and held in position, so
that the end of the couch roll is carried at the right height to allow

the new wire to be slipped over it.   The lower bearing is removed, and all parts that might touch the wire are wiped clean.   The new wire is then carefully slid over the lower couch roll, great care being taken not to kink it.   Kinks form very quickly and easily, and they practically ruin a wire.

115. Putting on the New Wire.—The roll of new wire is now placed on top of the lower couch roll, Fig. 46(b), spar A is replaced in the wire roll, and the wire is unrolled, as indicated by the arrows; the wire is, of course, far longer than is indicated in the figure.   Spar A, together with the wire on it, is carried toward the flow box sufficiently far to permit the breast roll to be placed inside of the wire, a few table rolls being replaced to prevent much sagging; the breast roll is slid on a plank (or rails), laid inside the wire, until it can be placed in its bearings, after which, the plank is removed, care being taken not to injure the wire.   Only the rolls under the wire (except the upper couch roll) may be left in the machine.   The new wire should be carefully examined for defects; if any are found, roll up the wire carefully and put it back in its box for return to the manufacturers; but don't blame the wire man for the result of carelessness in the mill.

Next put the supports and save-alls in their proper places, and then the table rolls, one by one; the suction boxes follow, then the carrying rolls, the guide roll, and, lastly, the stretcher roll.   The greatest of care should be taken to see that there are no loose parts or rolls that can possibly fall on the new wire; that top brasses, pins, screws, bolts, etc. are all in place; that the shower pipes are up, the doctors replaced, and that the guide mechanism is in place.   The palm or palms on the guide bar must clear the edge of the wire by about $\frac{1}{16}$ inch.   See that all pipe connections are tight.

The end of the save-alls should not be close enough to the breast roll to allow any stock to become lodged between them. Since the back of the breast roll passes down from the save-alls to the breast-roll doctor, it retains stock; therefore, a strong shower pipe should play on it just above the doctor, to wash accumulations off this doctor and through the wire or to one side, by a trough.   The doctor should have a felt or a rubber edge, to keep the breast-roll surface clean and to keep any stock from traveling up between the wire and the breast roll, which would cause ridges in the wire.   The pressure of the doctor against the breast roll should be as light as possible and still permit it to clean the roll.

Any extra pressure will act like a brake, which will increase the work that the wire must do in turning the roll. The pulp thus scraped off by the doctor may be made to fall into the save-all box.

116. Care of the Wire.—Proper care of the Fourdrinier part of the machine, either when idle or when being prepared for service, is extremely important; both for the sake of the machine itself and for the resulting saving in the expensive wire. Under careless management, the wire may last only a few days, when several weeks of service may be obtained from it, if properly attended to. Generally speaking, the life of the wire largely depends on the machine tender.

When putting on a wire, the little patches of hard pulp that stick to the rolls are sure to cause trouble, unless they are thoroughly removed. Again, when putting the wire on, kinks are very liable to be forced in it, and the bends so produced always develop into cracks. It is necessary that the seam on the wire be kept straight, and this cannot be effected unless the guide roll and stretch roll are square with the machine, and both are level.

117. Testing Squareness of Table Rolls.—The proper way to test the squareness of the table rolls across the machine is to measure with a tape line or a pair of trams (two sharp pointers, at right angles to and adjustable along, a long stick or bar), to ascertain whether the distance between the ends of the several rolls is the same on either side of the machine. Care should be taken to select the points at easy places where the measurement begins, and center-punch marks should be made to locate these measuring points. The punch marks should be made directly over the center of the journals of, say, the first press roll or the couch roll.

When satisfied that the measurements are the same on both sides of the machine, measure diagonally to see if the rolls are square with the machine; for instance, see if the measurements between the centers of the journals of the couch rolls and the breast roll are equal on either side. It is also quite as important to see that the measurement from the center of the front journal of the couch roll to the center of the back journal of the breast roll is the same as from the center of the back journal of couch roll to the center of the front journal of the breast roll.

These distances may be too great to be measured easily; but they can be checked by measuring diagonally from the couch-roll journals to the first table-roll journals, or to the suction boxes, making continual diagonal measurements until the breast roll is reached. The measuring should be done with a steel tape.

118. Leveling and Lining-Up the Table Rolls.—When the rolls have been squared, carefully level them across the machine. Line up the rolls by placing a tight wire from the top of the breast roll, and see that light just shows between the wire and the top of each roll; this wire should be drawn tight, from the top of the breast roll to the top of the guide roll. If the breast roll has been raised or lowered, the wire should be straight from the top of the breast roll to the top of the last table roll next the hinge or break in the table bars; see Fig. 27. If adjustments are required, they should be made by the millwright or master mechanic.

119. Squaring the Other Rolls.—The couch roll and all other rolls must be kept square with the machine; periodical checking of the squareness of the rolls will often prevent undue strains on the wire. The upper couch roll should be so placed that a plumb line dropped through the center of the journal will be nearer to the wet end of the machine than a line similarly dropped through the center of the lower couch roll. Great care must be taken in couching (off-setting) the top roll. First see that the distance between these plumb lines is the same at the front, or tending, side of the machine as at the back, or driving, side of the machine; second, that the amount of couch is as much as possible, without taking the weight of the upper couch roll off the lower couch roll and placing it on the wire. An average amount for the couch is about 4 inches, but will vary with the size of the rolls. Sighting over two straight edges placed on the faces of both rolls front and back is a good method of checking your work.

120. Amount of Stretch in the Wire.—The amount of stretch of the wire should not be tested by hand; it is much better to use a mechanical tension indicator at the stretch roll, and an ordinary spring balance may be used for this purpose. Records of wire tensions so obtained and recorded will give valuable information as to the effect of various tensions on the duration of a wire. Take care not to stretch the wire too much.

121. Starting a New Wire.—When starting a new wire, start slowly, have all the shower pipes working and the hose going, so

no stock can get between the rolls and the wire.   Note whether the wire seam is raised up; if so, pass it over the lower couch roll and flatten it lightly with a wooden mallet.   If the seam is raised up, it will cause bubbles across the sheet, because of the air it traps as the raised part passes over the breast roll.   This trapped air is forced through, and it makes its escape under the apron, carrying with it the frothy sizing compounds left by the waste water in the meshes of the wire.

122. Lubrication.—Lubricant of a good grade, preferably a clean mineral grease, should be used on the table journal bearings, and a mineral oil of approved brand, about 28° Be., on the other roll bearings.   The wire, which acts as a continuous driving belt with the lower couch roll as the driving pulley, has a great load to carry, and this can be largely decreased by proper attention to the lubrication of the bearings.

CLEANING THE WIRE

123. Souring the Wire.—If it can be avoided, do not clean the wire with acid; but if this appears to be the only effective method, dilute the acid with water—5 parts of water to 1 part of sulphuric acid.   The solution can be applied to the wire through the shower pipes on the inside of the wire.   This process is called **souring the wire.**   The weak acid solution may be applied on the wire as it comes over first wire roll.   Always pour the acid into the water.

A good way to clean a wire with an acid solution (sometimes a caustic solution is used for this purpose) is to make a water-tight box, in which the lowest outside wire roll can run.   The roll, turning in the solution, will then sour the wire evenly all over, and the wire will, in its turn, carry around enough solution to sour and clean the whole wire.   Be sure not to have the suction boxes in action while the cleaning process is going on; otherwise, the acid (or caustic) will then be lost before it reaches the dandy roll.   When the wire and dandy stop frothing freely from the acid bath, they are practically clean; then wash off all the acid with a hose, and clean out the water-tight box.   Keep this box clean or remove it.   Remember that acid acts chemically on the wire, and that it must therefore be well diluted and afterwards thoroughly washed off.

124. Pitch Troubles.—**Pitch** or **grease spots** in the wire may be removed by putting a strip of felt, about 36 inches wide, extending across the machine, on the inside of the wire; by means of a small jet or steam hose, about $\frac{1}{4}$ inch in diameter, the pitch can then be blown from the wire into this felt. This arrangement gives a sharp, direct blow of hot steam at the pitch spots on the wire, which removes them so quickly that it does not heat the wire. Care should be taken not to hold the steam jet too long in one place, since this would weaken the weave on account of the resulting unequal expansion of the wire. It may be mentioned that alcohol and ether are solvents for pitch.

While the stock is on the machine, pitch will sometimes accumulate in the meshes of the wire or on the suction boxes. If on the suction boxes, the boxes may be removed while the wire is running; then remove the pitch and replace the boxes.

125. Washing the Wire.—Wash the wire plentifully with a hose whenever a chance is offered; this keeps the meshes open, washes off the acid, prolongs the life of the wire, improves the appearance of the paper, and reduces the work on the suction boxes. Be careful, also, to play the hose well and carefully on the back side of the machine. Sometimes the dirt gets washed only from the front to the back side. Many of the troubles on paper machines are caused by the fact that the back side of the machine is not as easily taken care of as the front side; the machine tender should remember this when working on his machine, and should give special attention to the back side. The front side is not so liable to be neglected. When washing down with a hose, lift the dandy roll off the wire, so as to keep old froth spots from getting washed onto the dandy. Keep water off belts and motors, and remember that it costs money to pump water; don't waste it.

OPERATING DETAILS AND TROUBLES

WIRE, APRON CLOTH, AND SLICES

126. Action of the Wire Guide.—The wire guide can prolong the life of a wire or it may shorten its life, according to its mechanical condition. If the guide mechanism is kept in good, sensitive

working order, it will guide the wire without undue wear; but if it works stiffly, it ceases to be a protection and becomes a source of injury, by creasing and cracking the edges.

127. Kinks in the Wire.—A kink in the wire, caused by dropping a wire brush or by any other means, can be removed as follows: First grease the kink, or buckle, bring the part of the wire where the buckle appears over the stretch roll, then sour or wash the wire with acid (a 4 to 1 solution of sulphuric acid) right across the portion of the wire where the buckle appears. The stretch roll can then be set up until the buckle, or kink, disappears; then wash off the acid solution with a hose. A kink can also be removed by the stretch roll, in a similar manner, by heating the buckle or kink red hot, using a torch made of a handful of waste that has been dipped in kerosene and attached to a broomstick. The result of this is that the wire is softened and the kink is removed, instead of the wire being weakened by acid; and the strength of the wire is not impaired.

128. Care of Apron.—If the apron cloth, frequently called the **apron,** will not lie flat, but tends to buckle or roll up on the edge, drench it with hot water until it lies flat on the wire. If the machine is idle for a long time, put a strip of wet felt on the edge of the apron; then fasten the brass or metal angles or side pieces to the apron, as far under the deckle pulley as is possible without touching the strap. See Art. **57.**

129. Necessity for Uniform Flow of Stock.—When starting the stock onto the machine, the slices should be so adjusted as to keep the level of the stock higher on the side next the apron than on the machine side; in this way, the speed of the stock is kept approximately as high as the speed of the wire for high-grade paper. If the stock is flowing onto the wire at a slower speed than the wire is moving, ripples and waves, the so-called **fish tails,** will appear on the stream of stock up to the point where the speeds are equal. If equality of speed be not attained before the paper is nearly formed, the increasing viscosity of the stock, as it gets drier, prevents the smoothing out of the surface, and these ripples or waves become permanent; the paper then lacks uniformity of strength, finish, and thickness, and it will, in such case, often break before it reaches the calenders.

130. Regulating the Slices.—The slices are regulated to suit the kind of stock and the speed of the wire. When the stock is

fine (or slow) and carries water well, the slices should be kept down, especially when making wove paper; no more water should be used than is necessary to close the sheet, and as little shake as possible should be allowed. The suction box, or boxes, before the dandy roll should not draw too hard.

When making laid paper, the slices are raised a little higher above the wire than when making wove paper; more water is required, more suction is necessary on the first boxes, and the stock is generally more free. The stock being more dilute, the head back of the slice (if the slice be not raised enough) will force the stock to move more quickly than the wire, and some of the effects of the shake will then be lost.

When making light-weight papers, the tendency is to let the stock flow more slowly than the wire is moving. When this occurs, keep the stock back of the slices at a higher level, so as to create more head and get the necessary volume of stock for the same slice opening.

When the stock is flowing too quickly under the slices, which is often the case when making the heavier papers, reduce the head back of the slices until the speed of flow is the same as the speed of the wire, by increasing the slice opening or by shutting off some white water. If the dandy roll tends to rise, there is too much water in the sheet; when this happens, increase the suction on the first boxes and give more shake. The thicker the sheet the more shake that is required.

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STOCK TROUBLES

131. Manner of Running Stock.—When making envelope, cartridge, or any paper for which stock may have been kept too long, and is therefore **soft,** it is necessary to use plenty of water, raise the slices, and give a vigorous shake. Be careful not to give too much shake, or the edges of the paper will be thin, on account of the back washing from the deckle straps.

It is sometimes necessary, due to the poor design of the flow box and apron board, to check the flow of stock at certain points across the slices, with pieces of paper, etc., so as to get an even stream across the machine. Weights are often placed on the apron, in the stream of stock, to correct such unevenness of flow. At the places where these obstacles occur, trouble may be expected at the dandy. It is better to correct for these faults by raising

the slices a little, using more water, and increasing the flow from the box.

132. If the stock is long, and is also soft from long storage, run slowly; but, even then, do not expect a good sheet of paper. When the stock is soft and fine, it will look crushed, and it will stick to the first press roll; use as little shake as possible and as much suction as possible.

With soft, fine stock, weight the couchers well, and set the guard board close to the jacket, but keep the jacket wet enough to prevent rubbing off dust from jacket or board. Then use but little weight on the first press, and keep the wet felt fairly tight. If sticking still continues, use turpentine on the press roll, after the paper is down on the felt, and keep turpentine on the press roll until the tendency to stick and climb up the roll is sufficiently reduced.

133. To Keep Water in the Stock.—In making a high grade of paper on a long wire, the paper may have a dull, crushed look, more especially if it be a wove paper, on account of too much water leaving the stock at the table rolls before proper formation is accomplished. To remedy this, prepare the stock fine, allow the water to stay in the sheet, and allow the shake to get in its work, by lowering a sufficient number of table rolls to keep them from touching the wire. It may here be remarked that some paper makers do not believe in the possibilities of judiciously varying the number of table rolls in action.

It is to be noted that if the number of table rolls are reduced to the right number and the quantity of water is reduced to the right quantity, then the paper will reach the couch roll with a larger proportion of the sizing and loading originally placed in the beater than when more water is used and more table rolls are in action. It is common practice on high-speed news machines to remove several table rolls in the summer time, when the stock is freer, so as to prevent too much damage at the forming table.

By raising the breast roll, say 18 inches higher than the couch roll, a long wire can be used; this will carry the water well down to the suction boxes, and the machine can run at a speed of over 800 ft. per min. on such papers as news. An even greater inclination of the wire is used at high speeds, up to 1200 ft. per min. If it be desired to use plenty of water to carry the stock well down the wire, and it is desired to close the paper well by using

plenty of shake, the breast roll may be lowered, say 2 or 3 inches below the couch, and the amount of water may be used that is necessary when using a short wire; fine papers can then be made at 100 to 300 ft. per min.

134. Increasing Capacity of Machine.—By clear thinking and reasoning from the observed results of certain manipulations, the paper maker can largely increase the capacity of his machine, not only with respect to output and speed but also with respect to quality of finish and formation. He has control of the quantity of water and the amount of shake; he can, on the same machine, control the finish and felting by getting exactly the right amount of water out of the stock at the dandy roll; at the same time, he can have plenty of water in the stock at the slices, to allow the shake to get high speed and good felting. He can raise the breast roll and then correct the poor felting that may result therefrom, by removing some table rolls; he can again get good felting by lowering the breast roll, and may still maintain his speed by increasing the head back of the slice and also increasing the number of table rolls. The amount of the suction on the first boxes gives him another instrument for increasing the efficiency of operation, and this is also under his control. However, it is not practical or sensible to make experiments that would cut down production; unless the paper maker can estimate quite accurately what the result will be, it would be foolish to experiment.

135. When starting the paper machine on a new order, examine the stock; if it is free, increase the water supply. If this be not done, the screens will fill up and the wire will be flooded with excess stock. On news, kraft, wrapping, and cheap book, start with plenty of water, say 300 parts of water to 1 of stock, and let the excess return to the regulating box, through the save-alls and white-water pump.

On slow stock,—rag paper, fine writings, ledgers, bonds, etc.,— it is best to start with about 50 parts of water to 1 of stock, and then gradually increase the water supply, if found necessary.

136. Regulating the Suction.—If the stroke of the shake be too long, the stock will wash back from the deckle straps, thinning the edges and causing a mark about 2 or 3 inches from the edge of either side. Search between the slices and deckle straps for causes of feathery edges; these may result from striking of the

deckle straps against the slices. See that deckle straps have clean, square edges, and that they rest flat on the wire.

There should be a sufficient number of suction boxes on the machine to keep too much water from getting over to the couch rolls. It is well to use only about 7 inches of vacuum on all the boxes; but if there are not enough boxes, a greater vacuum must be used, in order to do the work. Bear in mind, however, that when 10 inches or more of vacuum is used, the life of the wire will be shortened. There should be at least 4 suction boxes. Too much suction on the boxes will sometimes prove to be an excessive load, and cause the lower couch roll to slip on the wire. If the box covers are of wood, see that they are planed smooth, so the wire will not be forced to follow the ridges it makes in the covers; also see that the box covers are thick enough to keep them from vibrating when a strong suction is carried.

137. Froth.—When making soft-sized paper, **froth** is liable to cause trouble; in such case, lower the slices and use more water, so the froth is kept back of the slices. Small bubbles sometimes escape down the edge along the deckle straps; this may be prevented by using a piece of paper, folded where the straps and slices meet. The bubbles that gather on the edge of a laid dandy roll can be kept away by rubbing a little oil on the dandy, just off from the edge of the paper, or by oil ng the wiper cloth, just over the edge. Do not spend money on patented froth-killing mixtures. A good formula is a mixture of linseed oil and bleach, half and half (1 to 1), with about a pint of turpentine added to every 5 gallons of the mixture.

138. Kerosene is also a good froth killer. Either kerosene or the mixture just mentioned can be advantageously used by suspending it in a 5-gallon can over the suction of the white-water pump. The drip of the froth killer should be at the rate of about 5 or 6 drops per minute. This can be controlled either by soldering a small radiator valve to the bottom of the can or simply by punching a small hole in the can and passing some lamp wick through it, so the hole can be plugged entirely by the lamp wick, if desired, or as nearly plugged as is necessary. Sometimes this froth-killing mixture is dumped into the beaers before emptying them; about $\frac{1}{2}$ pint of the mixture to a 1200-pound beater is sufficient. A good spray, preferably rotating or oscillating, over the pond or over the flow box is usually very helpful.

To keep the dandy roll free from froth when making laid papers at high speed, place a perforated pipe in front of it, so a little steam may be blown across the surface; this will keep it clean.

139. Enlarging the Watermark.—Sometimes it is necessary to have the watermark in the paper slightly larger than the size of the marks, or the distance between them in the paper must be slightly greater than the spaces on the dandy roll; in such cases, either the mark must be stretched or the paper must be stretched. First let the wiper cloth bear sufficiently hard on the dandy to slow it up; not so hard as to cloud the mark, but just enough to gain a little. Then speed up the first press somewhat, to get a little more stretch, and do the same at the second press. In this manner, a dandy mark may be stretched a full eighth of an inch.

Lack of uniformity in the dandy marks across the machine, if the dandy is straight, is probably due to improper crowning of the press rolls, which makes the paper either wetter at the ends than in the middle or the reverse of this. When the paper is not uniformly pressed, the wetter parts are stretched more on the dryers than the drier parts. When setting a dandy, be careful that the deckles and markings are right; that is, set it so that the edges of the paper come the proper distance from the marks. Count the circumferential bars on the dandy, from the edge of the paper to the mark, and make the number equal on both sides.

THE COUCH-ROLL JACKET

140. The Couch Roll.—Be certain that the upper couch roll is not couched too much; in other words, be sure that the weight of the upper couch roll is carried entirely by the lower couch roll, and that no part of its weight is carried by the wire.

In a perforated roll, the holes keep water and wool balls from collecting under the jacket, and thus causing the jacket to creep and move around the roll. These holes may convey quite a little water into the inside of the upper couch roll, the water being squeezed out by the nip between the rolls or by the squeeze action of the guard board. This water is drained out of holes in the head of the roll, and is led away. An old upper couch roll will, in time, accumulate enough slime and refuse on its

inside, from these holes, to cause trouble by getting the jacket spotted, and so dirtying the paper. Although this rarely happens, it is sometimes a cause of trouble, one that a paper maker might not think of, unless it had occurred in his previous experience.

141. Putting on a New Jacket.—When putting a new jacket on the couch roll, have a jacket of the right size for the machine and of the right character for the kind of paper to be made. The felt maker should be given full information as to the requirements to be met, and he should also be fully informed regarding any defects in the jacket and of any difficulties encountered while the jacket is in use.
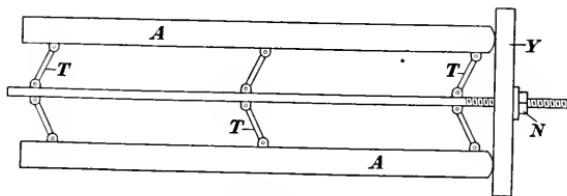
Fig. 47.

The old jacket is cut lengthwise, and the wire is driven forward until the jacket is clear. The new jacket is opened on the clean machine floor and carefully measured. Should it appear a trifle small, it can be stretched a little on a stretcher, such as is shown in Fig. 47. The hard-maple beams A, rounded on the outside, over which the jacket is stretched, are supported clear of the floor, and they are pushed apart by the toggle joints T, by turning the nut N against the yoke Y. This can be done while the upper couch roll is being prepared. There are several designs of jacket stretchers.

When the ends of the jacket are held tight by clamping rings, screwed or bolted against the end of the roll, or if the jacket is sewed fast, each end is punched, about 3 inches from the edge, with a row of $\frac{1}{4}$-inch holes, about 6 inches apart, and threaded with stout twine.

Take off the shower pipe and guard board, or lift it clear; also, the guard rail, if there be one. Remove weights and levers, and lift the upper couch roll well clear of the lower roll and the wire. *Be very careful not to walk on the wire or drop anything on it.* Clean the roll thoroughly, inside and out. To prevent

sweating of the roll, pour a few pailfuls of hot water on it, and wipe it dry just before putting on the new jacket.

Slip the new jacket over the lifting or porter bar used for putting on the wire, making sure that the nap shall be smoothed down as the jacket runs under the guard board; fit the open end of the bar over the extension of the upper couch-roll journal, on the front side, and lift the free end with the chain hoist. When the weight on the bearing is relieved, remove the bearing cap, and swing the bell-crank lever out of the way.

142. Couch-Roll Jackets.—The couch roll on a Fourdrinier serves two main purposes: the first is to transfer the paper from the Fourdrinier wire to the felt; the second is to squeeze out as much water as possible in the process. Consequently, in order to withstand this great pressure, the jacket must be very strong and firm; if it does not have the proper strength, this pressure causes it to become loose and to get baggy on the roll.

The older practice was to use a jacket on both top and bottom rolls, and this practice is still carried out in a few mills making very high-grade paper at slow speeds. At the present time, however, in most mills where jackets are used, only the top roll is jacketed.

Couch-roll jackets are woven in tubular form; this necessarily makes the production slow, since a great many threads must be woven to a single inch in a loom. These tubes are in lengths sufficient to allow several jackets of the same diameter to be cut from one tube, when finished.

When finishing jackets, all sizes are pulled to a diameter somewhat smaller than the diameter of the roll on which they are to be used. They are stretched while wet to a size that allows them to be slipped over the roll; and after they have been dried on the stretchers, this size is held until they are again wet up on the paper machine. When the water strikes the jacket, it tends to shrink back to its former size, thereby hugging the couch roll tightly.

The guard board has more to do with the length of service received from a jacket than any other one thing, since undue pressure on the guard board causes the jacket to wear very rapidly, and it has a tendency to make the jacket become loose and get lumpy on the roll. Guard boards should have a beveled edge and should be kept in good condition. If the jacket be shrunk on evenly and firmly at the start, and if proper care be

exercised regarding the pressure applied to the guard board, good results can usually be obtained. In late years, many of the news mills have been obliged to use a considerable percentage of jack pine in the manufacture of their paper, the pitch from which often accumulates on the jacket. If this pitch is not washed off with proper care, the life of the jacket is often very materially reduced.

Now with everything clean and clear, carefully draw the jacket over the roll until it overlaps the same distance on either side. Replace front bearings and remove lifting bar; draw up quickly and strongly on the twine threaded into either end, avoiding wrinkles, and tie in a knot that will not slip. Another method of fastening the ends is described in Art. **143**. Lower the roll until it makes firm contact with the lower roll; and if a clamp be used to hold the jacket, screw or bolt it firmly in place.

143. Couch-roll jackets get worn more quickly at the edges when the ends are so fastened to the head of the roll that the jacket is held at these points, although it may slip at the center. Couch-roll jackets are often fastened by sewing crisscross, across the heads, with stout packing thread. A better method of fastening the ends is to make a wood disk, Fig. 48, shaped on its edge like a frustum of a cone,

FIG. 48.

to which the ends of the jacket are fastened with copper nails. This ring is not fast at the roll; so if the jacket slips a bit, the ring turns with it, and the jacket is not strained. Couch-roll jackets that are clamped to the couch-roll heads with bolted metal plates do not last long.
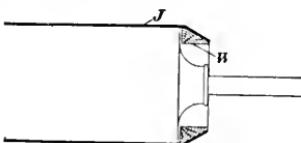
Having fastened the jacket, replace shower pipe, guard roll, and guard board, the edge of the latter having been planed to a true straight edge by the millwright.

144. Shrinking the Jacket.—The jacket must now be shrunk, to grip the roll tightly; this is accomplished by pouring several pails of very hot water across the roll very quickly; then start the wire, to turn the roll and enable any dry places on it to be wetted. When the jacket is firmly set, check further shrinking by starting the cold-water shower. Lower the guard board carefully, and set its edge so the jacket will be uniformly dry for its full length; use as little pressure as possible.

145. Starting a New Jacket.—When starting a new jacket on fine stock that is liable to stick to the nap, use as little weight on the roll as possible, and put the guard board down fairly tight. Before starting, pour a few handfulls of white clay or filler on the jacket, while dry, so the nap may be flattened and the jacket made harder by closing the pores with the clay or filler; or use a solution of soda ash in boiling water for the same purpose. When starting the roll, no water should be run on the roll, but a little clay may be put on it. When the shower on the working edge of the guard board is turned on, the pipe should be so turned that the jets will play on the front of the guard board, the water running down the front onto the jacket. If the jets play on the new jacket, the nap will rise, and the liability of *picking up* the paper will be much greater. But if the paper should pick up, a little turpentine or rosin size poured on the jacket will stop this.

146. Jacket Troubles.—A new jacket often causes trouble when colored papers are being made, since the picking up of fibers causes marks on the surface of the paper. If the guard board allows water to pass, the jacket will pick up stock as it runs onto the wire. Brushes that have been weighted with lead and placed on the jacket in front of the guard board, will keep the jacket clean; or the trouble may often be obviated by a vigorous rubbing by hand. For brushing jackets and felts, a brush of fine brass wire, or a piece of woolen-mill card, may be used. Turpentine is good for cleaning the edges of the couch roll; here the picking up is worst, which may be due to the dams in the suction boxes being too far from the edge of the paper.

147. If the jacket seam is not straight, that is, if it tends to lie diagonally across the wire, it may be straightened by increasing the couch-roll weights on the side where the seam is traveling ahead; this will produce a drag on this side of the wire, which will straighten the seam. Adding weight in this manner may, however, cause lumps of wool to gather inside of the jacket, and it may also make the paper thinner on one side; it is not the best practice to have the weights uneven to any extent.

The machine tender should be careful not to allow the upper couch-roll jacket to slip or twist. Should this occur, reduce the pressure of the guard board as much as possible and adjust weights on the upper couch roll, by easing up on the side that begins to lag behind. If the jacket gets so loose at the center that

it wrinkles because of a crown on the lower roll, take off the guard board and end clamp, and stretch the jacket into place.

When using a pressure roll, watch the lower couch roll; if there is too much suction on the boxes, the lower couch roll will slip in the wire.

148. A Patented Jacket.—Most jackets are woven endless tubes of high-grade wool, usually hard but fine. An English jacket that finds considerable favor is felted instead of being woven; it therefore has no warp, and it is the same all through and in all directions. Special care must be taken not to pull or wrinkle these jackets, with the guard board or otherwise.

THE SUCTION COUCH ROLL AND SUCTION BOXES

149. Amount of Suction.—As previously stated, some machines have pressure couch rolls, while others have suction rolls. In the case of a suction roll, the operator must be careful not to get too much suction in the suction boxes; for, if this occur, it will cause the wire to be slack after leaving the suction roll, and the wire will wrinkle. The best way to determine how much suction to use is to watch the wire after it passes the suction roll; if the wire gets slack, reduce the suction on the boxes until the slack wire below draws tight enough to run safely without wrinkling. On free stock, such as news, cheap tablet, catalog, wrapping, etc., it is practically impossible to get too much suction, because air penetrates the sheet easily.

150. Braking Effects.—The action of the suction boxes in drawing the wire down to the surface of the box, results in a brake effect on the wire. The greater the suction the greater this brake effect, which must be overcome by an added pull by the surface of the lower couch or suction roll, to drag the wire away from the suction boxes. The couch roll will sometimes slip under the wire, if the load it pulls is too great; this may break the paper on the machine, because of a momentary variation in the speed of the wire, unless the machine be driven by a sectional electric drive. The doctors on the breast roll and other rolls can also act as brakes. Anything that the machine tender can do to reduce the amount of pull on the wire by the couch roll, without spoiling the paper-making function, will increase the life of the wire.

151. Making the Wire Run True.—If the machine tender find that the wire guide will not keep the wire true, and the wire tends to travel to one side, then, provided the rolls of the machine are square, the trouble may be in the suction boxes. The wire will wear grooves in the suction-box covers, and sometimes the wire jumps the grooves, which causes it to be led to one side. When this occurs, the guides cannot help matters; the only remedy is to cut off the vacuum, by shoving in the rods, slacking the supporting bolts, and moving the box so the wire will not enter the same grooves. However, it is better, if possible, to take out the boxes and plane the covers.

MISCELLANEOUS

152. The Showers.—The patented shower pipes use less water per minute and, at the same time, throw a stronger stream; that is, a shower pipe that has had some thought expended on its design is not only more economical of water but it also does its work better. A rough figure that is approximately correct for the old-fashioned shower pipes, operating under 35 pounds water pressure, is $1\frac{1}{2}$ gallons of water per minute per inch of width of machine; the modern, patented shower pipes will save about one-third of this water.

If the shower pipes are not doing good cleaning work, increase the water pressure, if possible, and keep the holes clear. Use filtered water. The effect of an increase of water pressure on the shower pipes is to increase the force of the showers, it also increases the consumption of water. For instance, a 48-hole, old-fashioned shower pipe, $1\frac{1}{4}$ inches in diameter, with $\frac{1}{16}$-inch holes, spaced $\frac{1}{2}$ inch between centers, showed the following water consumption:

At 10 pounds pressure, 13.3 gallons per minute
At 20 pounds pressure, 15.5 gallons per minute
At 30 pounds pressure, 18.2 gallons per minute
At 40 pounds pressure, 21.6 gallons per minute
At 50 pounds pressure, 25.0 gallons per minute

In selecting the spray pipe, the nozzles that give the finest spray, and which throw the spray so it falls over a large area of froth, should be selected. These pipes are generally located over the flow box, over the apron, and just back of the slices; their sole duty is to reduce the accumulation of froth.

153. White Water.—The water that drains through the Fourdrinier wire, and which is often increased in volume by

Stock in Stuff Chest)
(97%-98% Water, 3%-2% Fiber)

At Regulating Box, Via Stuff Pump
(Same as Above)

White Water Added

At Screens
(99%-99.5% Water)
1%-0.5% Fiber

At Flow Box
(Same as Screens)

At Forming Table
(Same as Flow Box, Loses White Water
to Save-Alls Boxes, Leaving Sheet
of Paper on Wire)

White Water to Fan Pump   Fresh Water to Fan Pump
When Needed

At Suction Boxes
(About 93%-95% Water)

White Water to
Fan Pump or Fiber Recovery

At Couch Rolls
(About 90%-92% Water)

White Water to Fiber Recovery or to Waste

At Wet Press
(About 85%-90% Water)

Fig. 49.

water from showers, is called **white water, back water,** or **re-water;** it may also be water from the suction boxes and couch rolls. This water contains considerable fine fiber and mineral

matter. Most of it is lifted by a suction pump, and is used to dilute stock passing to the screens. What happens to the water in stock at the wet end of the machine is shown in the chart, Fig. 49. It is to be observed that about 50% of the water removed at the Fourdrinier part leaves the paper at the table rolls, with about 25% taken out at the suction boxes and 25% at the couch rolls; this leaves still 90% of water in the sheet going to the presses. Reference should be made to the diagram in Art. **21.**

154. Mesh of the Wire.—By **mesh** is meant the number of wires or openings to the inch. The wire used for coarse papers, as news or wrapping, is ordinarily 60- or 65-mesh; for writing or book papers, it is generally 70-, 75- or 80-mesh; while for special papers, as cigarette, a much finer mesh is required.

The alloy used for weaving Fourdrinier wires must be strong, tough, and flexible enough to weave into a flat cloth, and must be fairly resistant to acids. Extra wires are used at the edges, to give greater strength and wearing qualities. An alloy commonly used is 80% copper and 20% zinc. Phosphor-bronze wires are now used almost exclusively on newsprint machines.

155. Starting the Wire.—The following directions for starting a new wire have been condensed from Witham's "Modern Pulp and Paper Making:"

Great care must be exercised in starting a new wire, first being assured that everything is in proper condition before striking in the clutch, which operation should be performed very gently. A clutch should never grip so hard that the wire is started with a jerk. It is found to be a very good plan to turn the wire around slowly, at least once or twice, before the couch is set down, thus getting the wire in proper alinement before setting up. The stretch roll must not be tightened down until after the top couch roll is lowered into place.

The seam of the wire should be watched closely, so that neither end will run ahead of the other, but shall line up with the suction box or a parallel roll. All particles of hard material must be brushed and rinsed off before the wire is started up.

If for any reason the wire is stopped and the stock is shut off, the shake should also be stopped, since there is danger of shaking the wire into a wrinkle when it is not loaded with a sheet of paper and held down by the suction boxes. If anything happens that

makes it necessary to strike the wire out immediately, without first having a chance to shut off the stock, such stock should be thoroughly rinsed from the wire before attempting to start again. The weights should be removed from the couch levers, and, by all means, the suction should be broken where the stock has sealed the wire over the top of the suction boxes; this can be done by rinsing, or by rubbing the fingers across the top, to break the suction by letting air in.

Care should be taken to let up on the guard-board screws before striking the wire in, since the couch-roll jacket is frequently torn off by neglecting to do this. The guard board should never be let down onto the jacket until after the weights have been applied to the couch rolls; there is always enough slack in the couch-roll boxes, so that if the guard board is let down before the weights are applied, this slack is taken up in the boxes, and the guard board will necessarily have to carry the weight of the weights on the levers. In setting the guard board, great care should be taken to lower it horizontally, never allowing one end to go down before the other; otherwise, the jackets would be torn from the couch roll.

Stock should never be allowed to pile up high enough in the save-all to touch the wire.

PAPER-MAKING MACHINERY

(PART 1)

EXAMINATION QUESTIONS

(1) Name some advantages to a student in keeping a note book. What might be put in it?

(2) Name the principal parts of a Fourdrinier paper machine and mention briefly the function of each.

(3) Explain fully what happens to the stuff in the stuff chest until it reaches the paper machine.

(4) What is the other function of the water used to carry the paper fiber onto the wire?

(5) What happens to the paper if the excess water is not removed before the paper reaches the couch rolls?

(6) Explain a cause, and mention a remedy for (a) slime spots, (b) "fish tails," (c) thin edges, (d) crushed paper, (e) dandy marks.

(7) Describe the course of the water used at the wet end of a paper machine.

(8) Name some points you would insist on in ordering a stuff chest, and tell why.

(9) Explain the purpose of the regulating box.

(10) What is the characteristic of paper pulp on which the automatic regulation of stuff is based?

(11) (a) If you were building a mill would you install a save-all? Why? (b) What kind would you select? Why?

(12) Explain the operation and advantage of (a) a flat screen; (b) a rotary screen.

(13) Tell briefly the story of the invention and development of the Fourdrinier machine.

(14) Where are the following parts and what are they for: (a) flow box? (b) shake? (c) dandy roll? (d) guard board?

(e) apron?   (f) deckle straps?   (h) guide roll?   (i) suction box?
(j) stretch roll?   (k) slice?

(15) (a) What is the function of the couch press?   (b) How is this accomplished in the case of a suction couch roll as compared with the ordinary couch press?

(16) Explain the action of table rolls in the removal of water from the paper.

(17) (a) What effects are produced on the stock by raising or lowering the breast roll?   (b) using more or fewer table rolls?

(18) (a) Why is it necessary to have rolls square with the machine?   (b) how are they tested?

(19) What is the difference between a left-hand and a right-hand machine?

(20) How is the paper taken from the wire to the first press felt?

PAPER-MAKING MACHINES

(PART 2)

THE PRESS PART

DE-WATERING THE PAPER

156. Passing to the Press Part.—At this point, the reader is requested to turn back to Art. **52,** where the cut squirt is described and also the method of passing the paper by hand from the couch roll to the wet felt. It is well to note here that the paper can be picked off the wire by a rough felt and automatically placed on the first wet felt. This small auxiliary felt need be only a little wider than the strip of paper cut by the cut squirt; it may be carried on two or three rolls in a frame that can be moved to place the felt in contact with the wire and the first press felt. The only necessary condition is that such an arrangement be adjustable and removable; also that the small felt be rougher and more porous than the wet felt. The paper may be blown from the couch roll to the wet felt, that is, the narrow, squirt-cut strip can be so blown. A successful method of accomplishing this is to have the blowing pipe from which the air jets strike the wire at or near the edges of the narrow strip cut by the squirt. The paper is thus lifted down from the wire, and its momentum, aided by the air current, carries the strip across to the first felt. With a suction couch roll, the jet of compressed air may be directed from within the roll.

157. De-watering Devices.—Up to this point, the paper has been de-watered as follows: the Fourdrinier part of the paper

machine partly de-waters the paper by the action of the table rolls, which causes the water to drain out through the wire; when this process has gone as far as possible, the next step is the use of suction boxes, which suck out the water; the dandy roll smooths the surface a little, and when the paper has passed over the suction boxes, it has become strong enough to be squeezed in the couch rolls. After having passed through the couch rolls or over the suction roll, the next de-watering device is through the use of pressure; and as the paper passes from the wire to the wet felt, as much water as possible is squeezed out in the presses.

158. Per Cent of Stock and Water at Different Stages.—The following table shows the per cent of stock and water at various stages, from beaters to dryers:

	News (600 ft. per min.)		Book (300 ft. per min.)		All sulphite (400 ft. per min.)	
	Solids	Water	Solids	Water	Solids	Water
Mixture from beater.	3–3.5	97–96.5	4	96	4	96
Mixture going on wire	0.5–0.6	99.5–99.4	1	99	1	99
Entering couch rolls..	10	90	8	92	12	88
Leaving couch rolls...	13[1]	87	17	83	25	75
Leaving last press....	26–30	74–70	29	71	40	60
Leaving dryers	91–97	9–3	91	9	93	7

[1] It is claimed that, with a suction roll, the solids here will be 15%.

Water does not leave book paper as readily as it leaves news; hence, book paper leaves the Fourdrinier and enters the dryer part carrying a greater per cent of water than news does. The per cent of stock on book paper will be approximately the same as on papers where bleached sulphite stock is used. Water leaves paper made of unbleached sulphite more readily than from any other that has had the same preparatory treatment; therefore, more water can be pressed out by the couch action and also by the presses, the felts do not fill so easily, and a greater pressure can be applied on rolls. This grade of sulphite paper leaves the presses dryer than either news or book papers.

159. Referring to the sulphite part of the table, it is apparent that if the ratio of solids to water at the breast-roll end of the wire is 1 to 99, then it will take 9900 pounds of water to make 100 pounds of paper. In practice, somewhat less water is required, because the paper leaving the machine is not bone dry; it still contains about 7% of water. In calculating the amount of water necessary for the machine, there should be added the amount of water required for showers and washing; and there should be subtracted from the total initial supply of pure water estimated as necessary the amount of white water returned through the save-alls, fan pump, and screens.

DESCRIPTION OF PRESS PART

160. Purpose and Limitations.— The **press part** consists of a series of press rolls, through which the paper passes. The object of these presses is to squeeze out of the paper as much water as possible, without injury to the paper. While it is cheaper to remove the water by pressure rather than by evaporation, up to a certain limit, it is practically impossible to dry paper or pulp by mechanical pressure beyond the point where it has less than 60% of contained water; in fact, it is very unusual to find a press part on a paper machine that delivers paper at the dryer end containing less than 66% water, the remaining 34% being paper stock.

161. Course of the Paper.— The paper in the press part is conveyed on felts through the nip of the presses. The lower rolls,
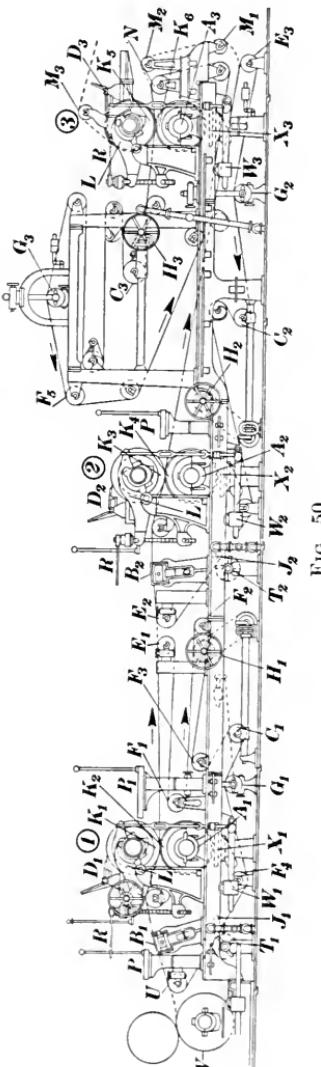
unless suction rolls, of the presses are rubber covered, and the upper rolls are made of hardwood or stone, cast iron or have a bronze outside casing. Fig. 50 shows a press part for high-speed news, which consists of three presses, the paper being reversed on the third press. Where only two presses are used, the paper is reversed at the second press.

The machine tender passes the paper from the couch roll V onto the felt of the first press at roll U; the felt carries the paper over the suction box B_1; from thence, it travels over a felt roll that is so placed that the felt and paper run down toward the nip of the first pair of press rolls K_1 and K_2. This arrangement keeps the water that is squeezed out by the press rolls from running onto the incoming felt and paper, since it is thereby forced to run down the near side of the lower press roll. This position of the felt roll also keeps air from being pocketed between the paper and the felt. The platforms P and P_1 allow the machine tenders to cross the machine.

162. As the paper passes through the first press, it leaves the felt and clings to the first upper press roll until it reaches the doctor D_1, by which it is scraped off and where it accumulates as wet broke in an inclined V-shaped trough, which is formed by the doctor blade and the back retainer wall that is built onto the doctor. This broke, or waste paper, is sent back to the beater room.

The bottom roll of the first press is covered with rubber; the upper press roll is of wood (maple), cast iron, cast iron with a brass sleeve, or stone (polished granite), the brass sleeve and stone rolls giving the best surfaces for enabling the paper maker to skin the paper off the upper press roll before laying it on the felt. The felt carries it forward, and it is passed by the machine tender from roll E_1 to roll E_2, on its way to the second press.

When the machine is provided with a cut squirt, this is set to give a strip from 3 to 6 inches wide. This is peeled off the upper press roll by picking the edge with thumb or finger nails, or blowing it off by compressed air; sometimes it is laid over a small roll, and placed on the felt, against which it is held until the drag of the felt is sufficient to pull the paper from the roll. It is fed into the nip of the second press and the cut squirt pushed across the wire. Sometimes this strip, widened to 8 to 10 inches, is carried well over the dryers before the full tail is cut.

If a cut squirt is not used, the machine tender gets as much as he can pull away from the front edge, then the back tender

peels the remainder gradually away until the paper is all on the felt. A prolific cause of profanity!

After leaving roll E_1, the felt passes around felt rolls F_1, F_2, F_3 to stretch roll C_1; then over guide roll G_1, to felt roll F_4, under shower pipe J_1, past whipper T_1, to roll U. The course of the other felts may be traced similarly. In Fig. 50, the felts are indicated by full lines, and the paper is indicated by dotted lines.

The doctor D_1, etc. is liable to scrape grooves into the upper roll; for this reason, it is supplied in many cases with a vibrating mechanism, which will be described later.

163. Course of Press Felts.—Before leaving the first press and following the course of the paper, observe how the first-press felt gets back to the first receiving roll. The first-press felt is a long one, and the extra length is sometimes carried to a roll in the basement. The first felt must be of rather open weave, to allow the large quantity of water that is squeezed out at the first press to pass through it. The second felt is generally finer than the first felt, that is, it is softer and has more nap, so as to produce a smoother finish on the paper as it passes through the nip of the press roll. According to the kind of paper being made and the treatment that the felt receives, the first felt becomes hard in the course of a few weeks, or even sooner. The pores are filled with filler that will not wash out, or the pores are forced to assume diamond shapes by the irregular stretch of the felt; as a consequence, it is usually necessary to remove the felt before it is worn out. But such a first felt is still good enough to use on the second press. For this reason, it is the general practice on news machines so to design the first-press part that the felts used on it are of the same length as those on the second press. In the design shown in Fig. 50, the felt on the second press is long, because the paper is reversed at the third press, and this necessitates that the second-press felt travel the full distance under the third press. The felt stretcher C_1 is actuated by the hand wheel H_1, by means of a sprocket chain and two sprocket wheels, in a manner to be described later.

It should be noted that some felt rolls have the felt lapped around them, so they may have two portions of felts pulling on them in the same direction; it is evident that such rolls have a greater pull exerted on them by the felt than those which the felt simply passes over. The latter rolls do not need to be as

large or as strong as those having the felt wrapped half way around them.

164. Size of Felt Rolls.—The usual sizes of felt rolls and their journals for different widths of machines are given in the following table, all dimensions being in inches:

Width of machine	100	125	150	175	200	225	250
Sizes of rolls	$6\frac{1}{2}$–7	$7\frac{1}{2}$–8	$8\frac{1}{2}$–9	$9\frac{1}{2}$–10	$10\frac{1}{2}$–11	$11\frac{1}{2}$–12	$12\frac{1}{2}$–13
Sizes of journals	$1\frac{7}{16}$	$1\frac{11}{16}$	$1\frac{15}{16}$	$2\frac{3}{16}$	$2\frac{7}{16}$	$2\frac{11}{16}$	$2\frac{15}{16}$

165. Course of Paper (**Continued**).—The machine tender, or the back tender, passes the paper from the first-press felt, as the felt turns down on felt roll E_1, to the second-press felt, as it turns up on felt roll E_2. The paper is carried by the second-press felt over the felt suction box B_2 (not always used), and over the felt roll, which is raised above the nip of the second press, in exactly the same manner as it passes to the first press. The doctor, the press housing and arm, the weights and levers, the stretcher roll C_2, and the guide roll G_2, are the same in all respects as those of the first press; the course of the felt, however, is different, as will be seen from the illustration.

The paper is to be reversed at the third press, in order to bring the wire side against the upper third-press roll, so the impressions of the wire may be removed by the smooth surface of the upper third-press roll. To carry the paper far enough forward in the machine to allow of its return in the reverse direction through the third press, it is necessary to make the second-press felt carry the paper to roll E_3. The machine tender takes the paper from the second-press felt at roll E_3, passes it over paper rolls M_1 and M_2, and places it on the third-press felt at roll N. If the paper were to pass direct to roll N, it would break. The paper rolls M_1 and M_2 give the paper plenty of slack and allow enough give and take in the pull of the third-press felt to permit the paper to be laid on this felt without undue strain, with its consequent breaks, since the narrow tail of wet paper is very weak.

At the third press, the paper enters the nip of the press rolls from a felt roll whose top is higher than the nip. The paper is carried around by the face of the upper press roll in the third press in exactly the same manner as in the other two presses, because it sticks to the surface of the roll until it is scraped off by the

doctor D_3, where it forms wet broke. The tail is skinned off the press roll by the machine tender, who passes it over the paper roll M_3, which is so supported by brackets that it is higher than the top of the upper press roll. From this point, the paper is passed over to the dryers. Skinning the narrow strip of paper from the roll requires skill and practice. Unless the machine is provided with compressed air nozzles, the edge is broken by the finger nail, quickly torn across, then pulled away, and the strip carried forward, over the paper-carrying rolls, and passed to the smoothing press or the first dryer.

If the machine has no cut squirt to cut the narrow lead strip, or tail, this is torn by the back tender or third hand as the paper passes from roll M_1 to roll M_2. He pushes his fingers through the sheet about 6 inches from the front edge and gently pulls away a narrow strip, skillfully keeping the tear vertical till the paper is safely on the dryers, when he gradually works the tear across the paper, finally breaking through the back edge.

166. The third-press felts pass around the stretch rolls C_3, the guide rolls G_3, and the felt rolls F_5, etc. On some machines, there is a very light belt from the felt rolls to the paper rolls; and the pulleys may be heavy enough to act as flywheels. It is decidedly advantageous to use ball bearings. An English patent provides for driving the bearing, which, in turn, imparts motion to the paper roll. When not so provided, it is usually necessary to start the rolls turning by hand.

Fig. 50 shows the characteristic features of a press part of a paper machine, including the reversal of the paper, which is generally done at the last press, regardless of whether there are two presses or more than two. The reader should study this drawing carefully, making himself so familiar with the run of the felts that he can see them in his mind, as it were; he should make a practice of sketching from memory the run of felts on paper machines; unless he is perfectly familiar with this detail, he cannot expect to understand press-part problems, which are frequently coming up for discussion and solution.

There is a slight increase in surface speed at each successive press, from presses to dryers, and from dryers to calenders; this increment is called the **draw,** a term also applied to the unsupported paper passing from one part to another.

DETAILS OF PRESS PART

PRESS HOUSINGS

167. Types of Press Housings.—Fig. 51 shows typical sketches
of four different designs of press housings; designs (a) and (b)
are for use on light, narrow machines, while designs (c) and (d)

Fig. 51.

are for use on heavier, wider machines. These designs will now
be considered in the order named.

The housing (a) has a swinging arm B, pivoted at P on frame
F, which carries the journals J of the upper press roll K. The
lower press roll K_1 is supported by journals in separate bearings
on the press frame, as indicated at A_1, A_2, A_3, Fig. 50. Arm B
is raised or lowered by turning hand wheel W, which turns screw
S through the pivoted nut N. The reader will note that this is
a lever of the third class.

In the case of the housing shown at (b), the operator raises or
lowers the arm L carrying journal J of the upper press roll K by

turning the hand wheel here indicated by the circle W. The shaft of this hand wheel carries a worm G, which meshes with the worm gear N; the latter acts as a stationary nut, and raises or lowers the lifting link S, thereby moving the swinging arm L about the pin P. F is a felt roll, and H is a hook for attaching the levers to put extra pressure on the upper roll. (See W_1, W_2, and W_3, Fig. 50.)

In the case of the housing shown at (c), the swinging arm L is raised or lowered by means of the hand wheel W; this housing is the reverse of that shown in (b). The bevel gear G on the hand-wheel shaft meshes with a larger bevel gear N, which acts as a nut and screws the lifting screw S up or down, thus raising or lowering the upper press-roll arms.

In the housing shown at (d), the swinging arm L (a bell crank) carries the upper press roll K, and is raised or lowered by means of a hand wheel, which is here indicated by the dotted circle W. A worm wheel G is keyed to the hand-wheel shaft and meshes with a worm gear N. The latter turns as a stationary nut for screw S, which causes screw S to push against the lower corner of the bell-crank lever L.

PRESS-ROLL WEIGHTS AND LEVERS

168. A Typical Arrangement.—Fig. 52 shows a typical arrangement of weights and levers for controlling the pressure of an upper couch roll, or an upper press roll, on the paper and on the lower roll. The hanger is made in four parts, the top part hooking into the swinging arm at H, Fig. 51(b), that carries the top roll; in Fig. 52, this part is simply an eye bolt B. The second part is the turn buckle T, which is used to adjust the length of the hanger. The third part H completes the turn buckle. The fourth part E is a long eye bolt that carries lever L, which presses with its short end under the flange of the press frame, as shown in view (b); it is hung, and pulls down on the center of the hanger E at P, holding hanger F on its long end. Hanger F is a tee-(T) headed bolt, the tee head resting on the long end of lever L. The nut on the bottom end of F holds in place a wedge-shaped washer casting C, on which rests the lever G, the hanger F passing through the lever. The short end of lever G turns on pin M as a fulcrum, and on the long end, the necessary weights are placed, as shown at W.

169. Pressure Produced by the Weight.—If the weight W, Fig. 52, be so placed that the distance d_1 from the center of gravity of the weight to the center of the pin M is 8 times the distance d_2 between the center of the wedge-shaped casting C and the center of the pin M, then the resultant pull downwards on hanger F is 8 times the weight W. If W weighs 50 pounds, the downward pull (p_1) on F is $8 \times 50 = 400$ pounds; this is
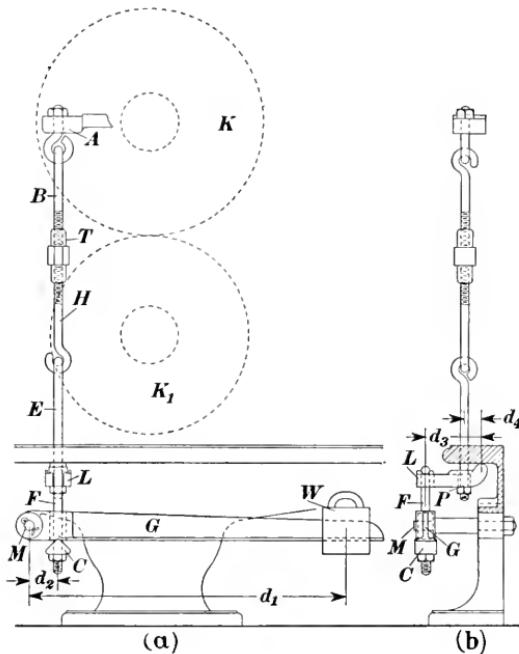
FIG. 52.

exerted on the end of lever L, the length of whose power arm is indicated by d_3, and the length of whose weight arm is indicated by d_4. Suppose these lengths are carefully measured, and it is found that $d_3 = 3 \times d_4$; then the resultant pull (p_2) on E is 3 times the pull on F, or $400 \times 3 = 1200$ pounds, which is exerted downwards on the swinging arm that holds the upper roll. The arrangement is evidently a compound lever, in which the power arms are represented by d_1 and d_3, and the weight arms by d_2 and d_4. Since $d_1 \div d_2 = 8$, and $d_3 \div d_4 = 3$, the velocity ratio of the combination (its mechanical advantage) is $8 \times 3 = 24$. Therefore, the pull on E is $50 \times 24 = 1200$ pounds, the same result as before.

In the housing shown in Fig. 51(b), the ratio of the lengths of power arm d_5 and the weight (pressure) arm d_6 is $d_5 : d_6 = 13:9$. Therefore, the total theoretical pressure exerted at the line of contact of rolls K and K_1 by the weight W is $50 \times 8 \times 3 \times 1\frac{3}{9}$ $= 1733\frac{1}{3}$ pounds. The velocity ratio of the entire combination is $8 \times 3 \times 1\frac{3}{9} = 34\frac{2}{3}$. Since there is a similar combination on either end of this roll, a pressure of at least $1700 \times 2 = 3400$ pounds will be obtained on the nip between the rolls by hanging a weight of 50 pounds on the levers G, Fig. 52, in the position shown; and to this must be added the weight of the top roll. It is, however, the weight per inch width of press roll that counts in pressing the paper.

170. Press-Roll Details.—When a machine is exceptionally wide, the top press roll is exceptionally heavy; and it is well to remember that it is not good practice to subject the rubber covering of the press roll to a pressure of more than 50 pounds per lineal inch of face, more especially, if the rubber covering be soft. This pressure is often largely exceeded to the detriment of the rubber covering. The machine tender should add only weight enough to cause the top and bottom rolls to meet at every point across the line of contact.

Rubber covers on lower press rolls were used at first, instead of wood and brass coverings, for two reasons: one reason was to save the felt; the other reason was to obtain a compressible roll, to compensate for insufficient crowning. The weights (W, Fig. 52) are used for obtaining the necessary compression of the roll surface, to close all gaps between the press rolls. On narrow machines, a softer rubber covering can be used than on wide machines; and the use of levers and weights on the press arms is more practical for the correction of the small errors in crowning that may occur on machines up to, say, 120-inch face of rolls. On wide machines, a closer approximation to the correct crown, when the bottom roll is first crowned, permits the use of a stiffer rubber covering and a less extensive use of levers and weights. Wide machines have very heavy upper press rolls; indeed, it is hard to design them so they will not exceed 50 pounds weight per inch of face.

Many machine tenders, when coming on their shift, alter the position of the weights on either the couch roll or the press roll, because every man has his own ideas regarding this; but the pressure should always be as light as possible on a wide machine.

If a press roll be not ground accurately, and is larger in diameter at one end than at the other, the paper will be dryer at the larger end, if the same weights are used.

Sometimes the steam in the dryers is not properly controlled, and one side, sometimes the side on the front of the machine, may be colder than the other side; so the machine tender tries to correct the lack of uniformity of drying by changing the weights on the upper press rolls; but this is poor practice.

Press rolls should be carefully calipered with micrometer calipers, the diameters being taken for every 6 inches of their length. A record should be kept of these measurements; and if the record be plotted, it will show the shape of the roll and be a useful guide to re-grinding. The plot is made by making an outline of the roll and indicating the diameters at the proper distances across it. The plot shows the diameter as measured at the distance indicated from the end of the roll.

THE VIBRATING DOCTOR

171. Why the Doctor Is not Stationary.—As previously mentioned, the doctor is used to scrape off and collect the wet broke from the top press roll and to collect particles adhering to the roll. If the doctor were to remain fixed in position while scraping, it would soon reproduce its own inequalities on the shell of the press roll, its edge scratching and scarring the surface. To prevent this, doctors are provided with an auxiliary mechanism that causes them to vibrate to and fro, and this motion results in a smoothing action between the edge of a doctor and the surface of the roll. The period of alternation (vibration) should not be an exact divisor of the time of one revolution of the roll; for instance, let a = number of vibrations per minute, and b = revolutions per minute of roll, then the quotient obtained by dividing b by a must not be an integer (whole number); otherwise, the same inequalities will come together at regular intervals. By giving proper attention to this detail, the roll surface and the doctor edge will remain smooth.

172. Description of Vibrating Mechanism.—The mechanism for vibrating the doctor is shown in Fig. 53. A worm casting W is fastened to the press-roll journal by set screws; it meshes with the worm wheel W_1, which is keyed to shaft S. As the top press roll turns, worm W turns with it, and this causes worm wheel

W_1 and shaft S to turn also, but very slowly compared with the speed of the roll. One end of lever L is fastened to the top of shaft S by a tap bolt T_1, the center line of which is eccentric to the center line of the shaft S; hence, the center line of T_1 revolves around the axis of the shaft when the shaft S turns, and this causes the end of lever L to turn around the same axis. This
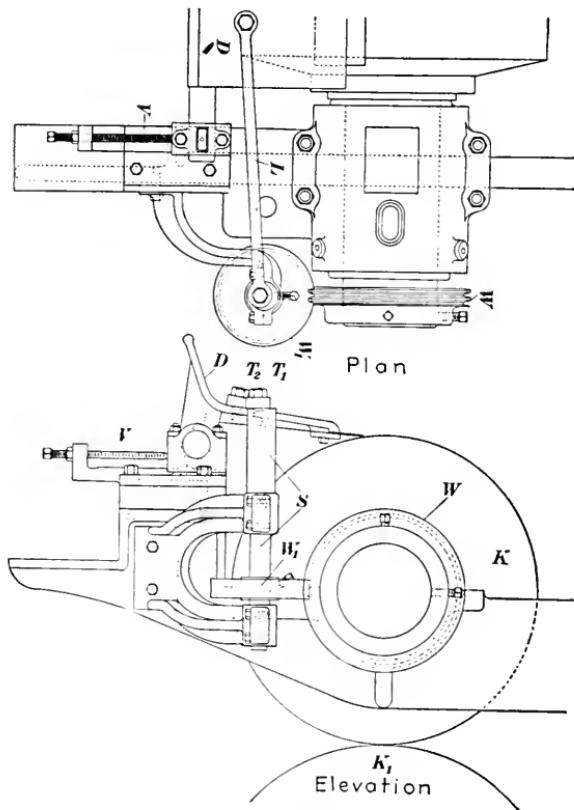
Fig. 53.

movement compels the other end of the lever, which is fastened by tap bolt T_2 to doctor D, to move to and fro a short distance in a direction that is across the machine, and thus gives the doctor a vibrating motion. The position of the doctor blade with reference to the top of the roll is adjusted by means of screw V; there are two such screws, one at either end of the doctor. The doctor blade may be made of steel, brass, hard rubber, or vulcanite; the latter two substances have less wearing action on the roll, and they do not rust or corrode.

SUCTION PRESS ROLLS

173. Lining Up the Suction Rolls.—Mention may here be made of the suction press rolls, which are now often used on the first press and sometimes on the second press. The mechanical operation of the suction press roll is much the same as that of the suction couch roll, and the same degree of care must be exercised, when installing one, to get the suction roll lined up with the rest of the machine. In this case, however, the upper roll is not eliminated.

The position of the suction box inside of the suction roll requires very careful adjustment. On account of varying conditions, it may be necessary to try the suction box in several positions before the correct one is definitely determined. Some experimenting may also be required in connection with the kind of felts used, it having been found that what works well in one mill is not always best suited to conditions in another mill. It is recommended that the felts used on a suction press roll never be turned over; hence, such felts need be napped on one side only. When running on a suction press roll, felts should last very much longer than when running over the old-style press rolls.

174. Construction and Operation.—The top roll may be of wood or it may be rubber covered or of granite, depending on the character of the paper being made. When given the proper crown, a wood roll works very well in most cases. The face of the suction press roll is straight, and all crowning that is necessary must be given to the top roll, the function of which is to smooth the surface of the paper. If wet streaks appear in the sheet as it leaves the suction press, it is certain that the top press roll is either unevenly weighted or is incorrectly crowned. The top roll should not be weighted any more than is absolutely necessary, since the suction of the bottom roll does most of the de-watering. This latter feature accounts for the ability to make a bulkier sheet over suction rolls. As it leaves the suction press roll, the sheet should be carried up over a draw roll of small diameter; if left on the felt, the sheet will have a tendency to absorb moisture from the felt.

175. As fast as any water is pressed out by the top roll, it is immediately carried away by the bottom suction roll; this eliminates the usual pond of water that collects at the nip of plain press rolls, which is caused by the up-coming surface of the plain bottom roll constantly carrying the pressed-out water back

into the nip of the rolls. This action further eliminates blowing, crushing, felt marking, and such kindred troubles as are caused by the objectionable pond of water that is always seen at the nip of plain press rolls.

Large volumes of air are constantly being drawn through the felt and into the suction roll; this action tends to keep the felt open and clean, so that less frequent washing is required. On machines making krafts and manilas, for instance, no felt washing is done, except at the time of the regular weekly shut down.

The suction press largely prevents first-press breaks, irrespective of the condition of the stock and of the speed of the machine. The atmospheric pressure holds the sheet down on the felt, while it passes over the suction area, with a force sufficient to overcome its natural tendency to stick and follow up on the top roll.

FELT SUCTION BOXES

176. Description of Felt Suction Box.—Felt suction boxes are similar in design to the wire suction boxes, except that no arrangement is made for reducing the suction area when a box without cover is used; that is, the rubber piston and the adjustments for it are omitted. The felt suction box shown in Fig. 54 is made from a pipe *P*, on top of which is a trough *A* for the purpose of keeping the felt *F* from actual contact with the pipe and closing the holes *H*, which are 2 inches in diameter. As the felt passes
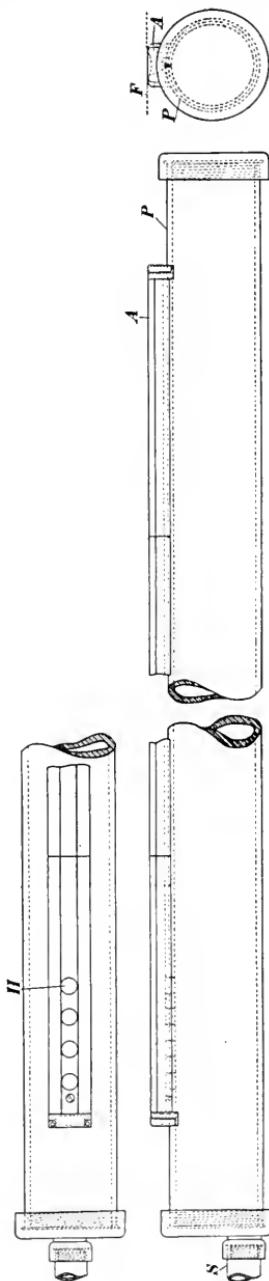
Fig. 54.

over the trough, the suction tends to draw the felt down into
the trough, up to the holes H. Since the felt is being stretched
tight as it moves, the force of the suction simply draws
the felt down, as indicated by the dotted line in the end view,
just enough to make the contact between the felt and the edges
of the trough sufficiently air-tight and water-tight to allow the
strip between the edges of the trough to have a part of its con-
tained water sucked out and drawn into the pipe P. The suction
box is drained at S. A perforated wood top similar to the type
used on the wire is preferred by many, who claim this type is less
wearing on the felt.

177. Operation.—There is no particular need for altering the
width of the suction area of a felt suction box; because the felt is
always wet, whatever the width of the paper being made, and a
felt suction box is used to dry the felt. However, the limiting of
the length of the active suction area to the width of the paper will
give a better vacuum.

Felt suction boxes are generally placed below the felts, just
before they enter the nip of the first and the second presses. If
the felt be kept as dry as possible, the presses are helped in their
work of pressing the water out of the paper into the felt that
carries the paper between the presses. The edges and tops of
felt suction boxes must be kept as smooth as possible, to guard
against damaging the felt as it passes over the box and is dragged
into it by the suction.

Felt suction boxes are built in many ways; a pipe suction box is
here described, not because it is superior to other designs, but
because it illustrates better the principal features of a good suction
box. The use of a perforated cover, similar to that on a wire
suction box, is allowable, provided there is a smooth surface
and no sharp edges that will wear the nap off the felt. Such a
cover is made of wood, with diagonal slots, which overlap enough
to provide a drying action over the whole width of the felt.

It must not be forgotten that the suction box acts also like a
brake on the felt, and that a heavy suction must necessarily
shorten the life of the felt.

PRESS-FELT STRETCHERS

178. A Typical Design.—In Fig. 55 is shown a typical design
of a hand-operated stretcher for a press felt. The press-felt
roll R, which carries the half lap of felt, is supported by journals

that turn in the brackets F; and a screw thread T, Fig. 56, in each portion of the brackets fits inside the brass pipes P and P_1.
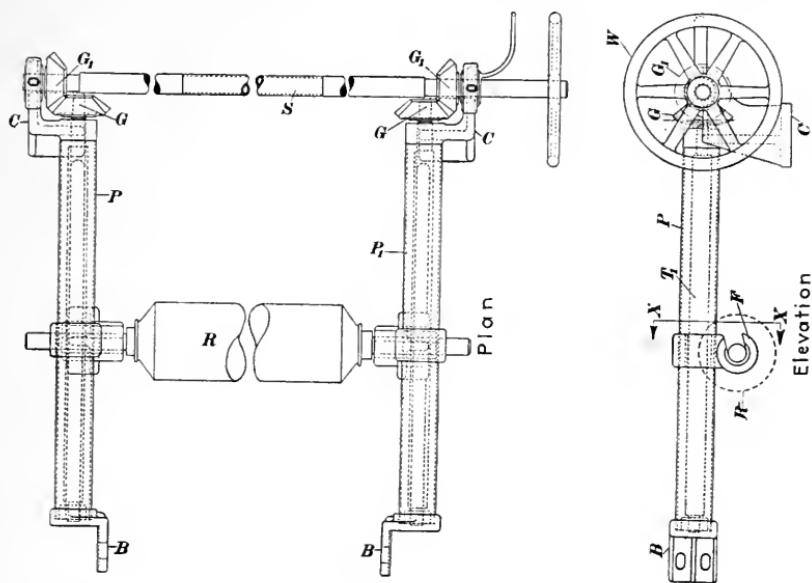
Fɪɢ 55.

In both pipes, there is a slot throughout nearly its whole length, to allow the brackets to slide along the outside of the pipes and also to project inside, so as to engage the threaded shaft T_1 that runs inside of the pipe. Fig. 56, which is an enlarged sectional view, shows this detail more clearly. The screw T_1 can turn, but cannot move otherwise. The screws have bevel (miter) gears G at one end, the gears meshing with them being on shaft S. By turning hand wheel W, shaft S and the miter gears revolve; this causes the screws in the pipes on either side of the machine to turn equally until the brackets carrying the felt roll are in the correct position to keep the felt in the state of tension required. Fig. 55 shows the stretcher furnished with a bracket B on one end of
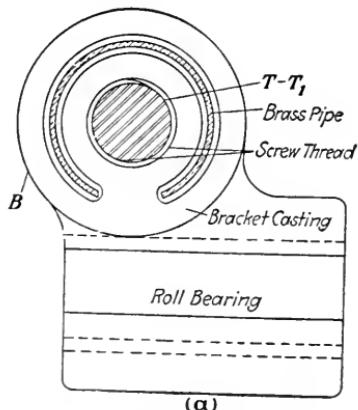
Section on X-X Fig. 55 (Enlarged)

Fɪɢ. 56.
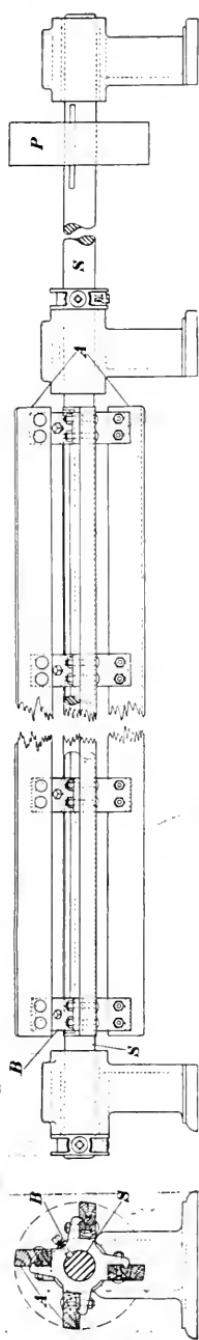
Fig. 57.

each pipe, to bolt to the side of a housing or upright casting, and a bracket C on the other end, to bolt to the press frame.

179. Velocity Ratio of Stretcher.—This stretcher gives the machine tender a velocity ratio of several hundred to one, according to the pitch of the screw and the other dimensions. Fortunately, the efficiency of such a piece of machinery is not over 25%; otherwise the felts would be overstretched, more than they are now on many a machine.

It is customary to have a cam arrangement that will throw out the gears on the front side, so the back end of the stretch roll can be operated forward or backward of the position of the front end, in order to make up for inequalities in the length of the felt.

FELT WHIPPERS AND SHOWERS

180. Felt Whippers.—The felt whipper, see Fig. 57, is designed with 2, 3, or 4 blades A, which are bolted to spiders B. The blades are made almost always of wood, and the outer extremities are rounded to an arc of a circle, as shown. Brass pipes may be used instead of blades. The spiders B are mounted on a shaft S, which carries the driving pulley P. The whippers are placed on the outside of the felt; they revolve at about 125 r.p.m., and in a direction such that the edge of the blades will not knock the nap off the felt. The rapid motion of the whipper causes the felt to vibrate forcibly against its blades, which beat out the dirt from the felt. A strong shower (J_1 and J_2, Fig. 50) is directed against the inside of the felt, to wash out the loosened dirt. The shower is generally placed after the whipper (in the direction

in which the felt is traveling), though some designers prefer to place it before the whipper, as shown in Fig. 50. The pulley P is belt driven from the nearest convenient driving shaft of the machine. Care should be taken so to adjust the position of the whipper that the blades will not scrub against the felt, thus wearing out the felt; it should beat the felt with quick, sharp blows, which do not tend to scrape off the nap. Felt whippers are almost always omitted on fast machines.

181. Showers.—There are several patented attachments for washing felts without stopping the machine; for the most part, these consist of a shower to distribute warm water, soap, or a chemical solution, and a suction box to draw out the dirty water and loosened dirt. On some machines, a pair of squeeze rolls are used to remove the water used for washing the felt.

Some experiments have been made in connection with the use of a steam jet instead of a shower; but the higher temperature is apt to shorten the life of the felt.

GUIDE ROLLS AND PAPER ROLLS

182. Auto-Swing Guide Rolls.—Fig. 58 shows the guide roll G_1, Fig. 50, in greater detail. The bearing of one journal of the
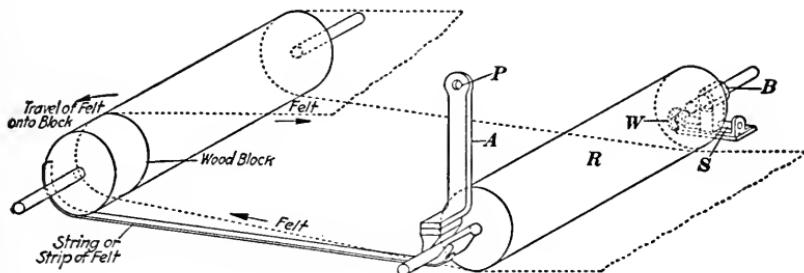
FIG. 58.

guide roll R is hung at P from a pivot on the tending side of the machine. The bearing of the other journal is carried in a bracket B, which is moved by an adjustable hand screw S. When the hand wheel W on the end of this screw is turned, the bracket carrying the guide roll is caused to move by means of the screw thread that is tapped in the bracket, and in which the hand screw turns. The position of the roll is so adjusted by this

means that the felt has a slight tendency to come to the front (tending) side of the machine.

The front journal, whose bearing is in the swinging arm A, is connected by a string or strip of felt to a cylindrical wooden block that fits loosely on the end of an adjacent felt roll (as F_5, F_4, Fig. 50). When the felt travels to the front side of the machine, it climbs onto this wooden block and turns it; this causes the string to wind up on the block and pulls the guide roll toward the block, thus correcting the travel of the felt. The principle is the same as that explained in connection with the wire guide roll. Fig. 58 shows the arrangement in perspective. It is customary so to hang the front end of the guide roll that the felt will be guided forwards again when the felt has left the block after the travel has been corrected. When the felt has left the block, a counterweight draws the string back to its former position.

183. Paper Rolls.—Since the paper is weak when wet, it is important that the rolls over which the paper travels shall turn very easily; for this purpose, the bearings must be well lubricated. Ball bearings are a distinct advantage here. An English invention provides for driving the bearing, the friction driving the roll, when idle, a little faster than the paper speed.

MANAGEMENT AND CARE OF PRESS PART

CARE AND TREATMENT OF FELTS

184. Taking Off the Old Felt.—The method of putting on a new felt will now be described. The old felt is cut across the machine and rolled up by hand, the press part being run slowly. If the old felt is to be used again, as is sometimes the case with a wet or first-press felt that is considered good enough to use as a second-press felt, or if it is to be washed, the old felt is taken out as follows: Clean the ends of press rolls, bearings, etc., thoroughly; slack up on stretch roll; raise upper press roll by means of the housing (lever), and pull out the old felt from between the rolls; lay the felt over the upper-roll bearing; lower front end of upper roll, and slip yoke or loop over the journals of the upper and lower rolls; raise again on the lever, which will lift lower journal from its bearing and permit the removal of the

pedestal; take out lower side of old felt; the pedestal is now replaced and the rolls lowered. The felt is now outside the press rolls, and it may be removed by lifting the ends of the felt rolls and slipping the felt over them.

185. Putting On a New Felt.—All grease and dirt must now be thoroughly removed from the frame and from the front ends of the rolls, and from any place the felt may touch; the trough under the roll is removed. The new felt should be laid out full length, preferably on the foot bridge across the machine or on the clean tending floor, with the nap of the felt lying down with the run of the paper. The felt is not laid out full width, but is doubled on itself in folds until its width is reduced as much as possible. It is a good plan to lay out and arrange the felt on the clean floor of the felt room. Don't walk on it. The top press roll is then raised by the housing, and the felt is placed between the journals of the two press rolls, with the nap so it will lie down when the felt is running, the cap on the lower roll being removed, and the journal and bearing wiped clean. The top press is then lowered until the steel link is in place over the two press journals. The link is inside of the felt, as shown in Fig. 59. When the link is in position, the top press is again raised by means of the mechanism already described; this raises the lower roll also. The bracket and bearings under the lower roll are then removed, and the frame and journal are wiped clean.

Fig. 59.

The felt is then passed over the end of the lower roll, and the bearing is carefully replaced. The rolls are lowered, the journal of the link is removed, and the top roll is raised until the felt can be spread out between the rolls. The felt is then pulled out lengthwise, so that it extends, while still as narrow in width as possible, along the inside of the machine in the path in which it is to travel. When a machine tender reaches a felt roll, as he is pulling out the felt along the machine, he lifts the roll out of its bearing and puts the felt over the end of the roll; and this is done with all the felt rolls that run inside the felt, if the felt is
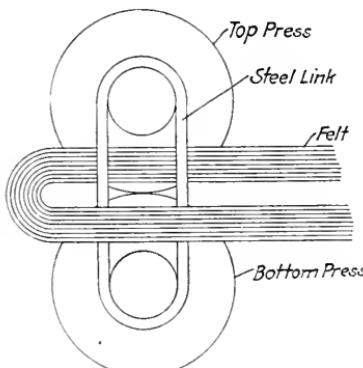
long enough. If necessary, the stretch (or hitch) roll is taken
out and put in last.

The felt is now in its proper place, but it is all rumpled up.
It can be edged across the machine gradually by running the
press part slowly, with the top roll down just enough to catch
the felt and pulling the felt across, using the guide roll to help in
doing this. While it may take longer, the felt will last longer
than when it is pulled and hauled across the width of the machine
by main force. Give the felt time to adjust itself, without
trying to increase production by gaining a few minutes at the
expense of the felt.

186. Wetting the Felt.—When the felt is across the machine
and the stretch roll is in place at its shortest stretch, the upper
roll is lowered and the felt is wetted. The wetting should *not*
be done with a hose, because it is very easy to spoil a new felt
by getting too much water in one place; a buckle caused by such
action cannot be removed. A shower pipe across the machine
should be used to wet the new felt gradually, care being taken
that the felt is not moving until a steady, even stream of water is
flowing over one roll across the full width of the felt.

The foregoing description of the method of replacing a felt is
applicable to all felts on press parts. On a cylinder or Harper
machine, there is more than one pair of presses, but the method of
placing the felt over the press rolls is practically the same in all cases.

187. Felt Marks.—Felt marks are the principal cause of
many troubles that develop at the press part of the paper
machine. The phrase "felt mark on the paper" is usually a
misnomer; it is the impression made by the threads of the felt
only in the case of old or too coarse felts, but is generally applied
to the defects in the paper caused by the gradual filling in of spots
in the felts meshes, which make the felt harder; the final result
is the accumulation of stock and filler, which destroys the ability
of the felt to press water from the paper, and a blotch is formed.
The water can escape when pressed out from the paper only by
passing through the felt meshes at the side of these spots. The
only remedy for this trouble is to clean the felt. When the
felt is new, and if the lower rubber-covered roll be not too hard,
a new felt should run satisfactorily for 48 hours without washing;
but, as the felt ages, the time between washings is reduced, and
felts finally have to be cleaned every 24 hours.

188. Washing the Felt.—The felts are washed on the machine as follows:

Remove all weights and levers; then slack the felt by moving the stretch roll back as far as it will go. Turn a strong stream of clean water on the felt, and push the felt on itself, toward the center, until there is a clear space, about 2 feet wide, from both ends of the rolls. Allow the felt to run in the water this way until clean, or for about 45 minutes in the worst cases. When it is observed that the water that is being washed through the felt is coming away clear and clean, it indicates that the felt has been washed sufficiently. It may then be pulled flat by gradually drawing the edges to the front and back sides of the machine; keep the hands away from rolls, avoid danger. Before pulling out the felt, clear it of wrinkles; if it be a double-napped felt, turn it over, so the outside will be on the inside; this will insure that the felt wear uniformly on both sides; it will also give a longer running time between wash-ups, because the newly-washed, dirty side of the felt is now on the inside, and the water pressed from the paper that leaves the felt from this side will carry off all the fine particles in the felt that may have remained after the felt washing. A weak solution of soap or soda ash is sometimes poured on the felt to assist in the cleaning. (See also Art. **181.**)

189. Care and Life of Felts.—A felt that is properly cared for should give 3 or 4 weeks of service on a fast news machine, which is very hard on felts, because of its high speed and the quality of the stock. On the slower running book machines, there is no reason why a felt should not last much longer. The elimination of rolls running on the outside of the felt lengthens the life of the felt. Such rolls gather particles of fiber, forming lumps that dirty the felt.

With good, smooth, brass-covered felt rolls of proper stiffness, with the upper press roll kept in good, smooth order, with the rubber-covered roll not too hard, and with the right amount of crown, the machine tender who exercises common sense regarding the amount of tension he puts on the felt at the stretch roll, may solve all the mysteries of how to get the longest wear, the longest run between wash-ups, together with a minimum of breaks and felt marks.

190. General Rules for Washing Felts.—At this point, it is advisable to give some instructions regarding the proper washing

of felts.   Cases are known where a felt has been run in the washer for nearly a full day; such treatment, of course, practically ruins the felt.   The following are general instructions for the proper washing of felts when the washing is done off the machine:

The temperature of the water should not exceed 120°F.; that is, it should not be hotter than one can comfortably bear when placing his hand in it, since a higher temperature injures the wool fibers.

The quantity of soap to be used varies with the amount of dirt to be removed from the felt, and with the amount of size that has been used on the paper; however, enough soap should be used to give a good lather.

Use a good neutral soap that rinses out readily, and do not use strong alkalis, because alkalis containing caustic will dissolve wool fibers.   There are brands of soap that have been specially prepared for this purpose, and one of these should be employed; the ordinary soap used about the mill is not satisfactory for felt-washing purposes.

If felts are washed in warm water, it is much better to reduce the temperature of the water gradually, while the felts are being rinsed, until the natural temperature of the water is reached; sudden changes in temperature change the original texture of the felt.

The felt should not be run in soap more than 20 minutes, and it should be rinsed only long enough to wash out the soap, say another 20 minutes.   If a new soap is bought, try it out on a test strip of felt.   Never use free acid on a felt.

191. Preservation of Felts and Jackets.—During the Great War, the United States Government studied the question of conservation of essential industrial materials.   The following recommendations made with regard to felts are worthy of careful study:

Watch the stock carefully, and keep it in a cool, absolutely dry place—moisture causes mildew and destruction of wool fibers. Felts and jackets should, if possible, be kept in their original papers, tied tightly; and see that there are no holes in the papers. Keep the felts clean; dirt injures them and attracts moths. Keep the whole felt room clean and in good order.

Use moth preventives freely and frequently; strong tar paper is good for this purpose, and the shelves should be covered with it.   Flake naphthalene is the best preventive, but it evaporates and must be renewed.   Sprinkle the felts thoroughly with the

naphthalene and scatter it around the felt room. Examine the stock at least once a month for traces of moths or for other injury. Use the oldest felts first.

Handle the felts with care when taking them to the machine. Felts are bulky and heavy, and they may be torn by catching on a nail or anything sharp; put them down only in clean places. Clean all journals and bearings before putting on felts, to keep the felts free from grease.

Above everything else, the life of a felt depends on the condition of the machine. See that all press rolls are turned with the proper crown to assure the very best running conditions; press or felt rolls that are in bad condition, rough suction-box covers and whippers, and badly made spread rolls, often reduce length of service 50%, or even 75%.

See that every roll turns freely; cylinder bearings should be carefully watched. All felts are subjected to great strains lengthwise, cylinder felts especially. Don't stretch the felts too tight. A large percentage of felts are ruined by running under unnecessary strain.

Felts on idle machines deteriorate almost as fast as when running. When shutting down, raise the top press roll; see that the felt does not come into contact with iron, as rust quickly fills the pores; see that the air can reach it at every point, so it can dry quickly and thus prevent mildewing.

Use care in handling jackets; they are tough and strong, but that is no reason for rough treatment. Be careful in stretching, shrinking, and tying down (lacing); watch the condition of the guard boards; above all, don't set guard boards down tighter than is necessary. Don't take off felts before they are worn out; get all possible wear out of them, even at some risk of a shut-down during the week. Superintendents and foremen should examine felts on machines before allowing them to be taken off and new ones given out. Don't make blankets from felts that can be run longer; by observing this one precaution alone, some mills have increased the life of their felts by weeks.

Carefully wash and dry all used felts, and keep them as clean as possible; their value depends on their condition. Don't destroy even small pieces of worn-out felts; every pound can be used for some purpose.

For reasons of economy and good business management, superintendents, foremen, and machine tenders will observe

all the foregoing precautions and many more that will occur to them in practice. In the long run, greater production will be obtained by not being careless about the condition of machines or in the use of felts and jackets. Take time to put everything in first-class condition; the time thus spent will soon be made up.

192. Tension of Felts.—While it is very important to consider the tension of the felt, it is equally important that the seam be kept straight across the felt. The seam will run ahead on the ends or at the center, according to the condition of the rolls and

Square Openings
in Mesh

Diamond Shape
Openings in Mesh
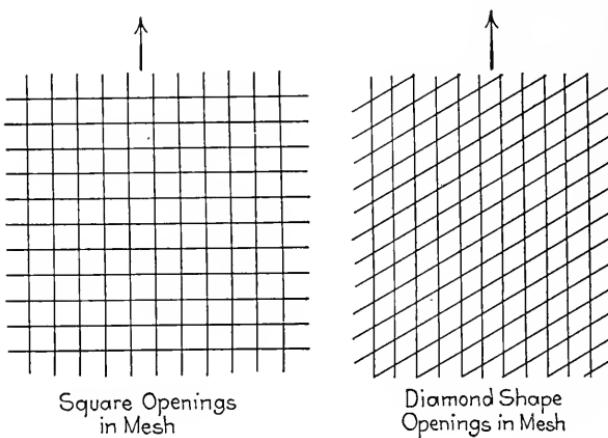
Fig. 60.

the amount of crown used. When the crown is excessive, the seam will run ahead at the center. When the felt is unequally stressed in this manner, the meshes are partially closed, due to the diamond shape that they are thereby forced to assume; this effect is illustrated in Fig. 60. The left-hand part of the figure shows the meshes (greatly exaggerated) when the felt is running properly, while right-hand part shows the meshes when distorted by excessive crowning, or by having one side run ahead of the other.

When first put on, a felt can run under much less tension than later, and distortion of the weave has less effect, because the felt has enough nap to offset the extra pressure of the rolls. Further, under these conditions, the tension is not severe on the felt, and it would not then be absolutely necessary to correct for a crooked seam; in fact, the remedy might be worse than the disease, the felt being caused to widen excessively and to run against the frames.

193. Influence of Tension on Width of Felts.—The extra width on new felts must not be trimmed off when they are new; it will be needed later, when the felts become thin with wear. They should be ordered of correct width. When it has become worn, it is obligatory to increase the tension on a felt, in order to open the meshes and thus more readily release the water. The width of a felt is controlled to a certain extent by its tension: when the tension is great, the felt naturally narrows, and it spreads when the tension is relieved.

194. Widening Felts.—When a felt has been narrowed by being stretched under the tension, it can be widened again by slacking the stretch roll and making one of the inside rolls (around which

Fig. 61.

the felt wraps more than a quarter of a circle) into a worm. This latter operation is effected as shown in Fig. 61, by tacking a strip of felt to a wooden roll, or by fastening a brass strip to the roll either by means of countersunk screws or by solderng it to a brass roll. Examination of Fig. 61 shows that the worm is double threaded and that it has right- and left-hand threads, the part to the right of A being left-handed and the part to the left of A being right-handed. As the felt moves in the direction of the arrow, the friction between it and the roll causes the roll to turn also, and the threads tend to push the fibers away from the center A, which widens the felt.

A simple felt spreader may be constructed of two light wood rolls, which are a little more than one-half the length of the felt rolls; these are supported under the felt, with their axes making a large angle with each other (say 160°), like a shallow V, the apex of which points to and meets the center line of the oncoming felt. These rolls, of course, are dropped or otherwise taken out of contact with the felt, when it has been widened enough.

195. Guiding the Felt.—To guide a felt, the end of the guide roll must be moved in the direction in which the felt is running, if it be desired to make it travel away from that end; but if the

end of the roll be moved against the run of the felt, the felt will travel toward the end that was moved.

If the seam, or blue line, of a felt be not parallel with the axis of a felt roll, *i.e.*, if one end be ahead of the other, the end ahead can be brought back by increasing the stretch on whichever end of the line is ahead. The felt should be watched carefully whenever a roll is shifted, to see that its position is not altered. In cases where both ends of the seam are even (parallel with the axis of a felt roll) and the center is drawn back, add extra worming in the center of the roll, or at any place where the felt lags back. Another remedy is to wind cotton twine (or a strip of paper having a little paste on the ends) around the roll, in line with the lag places; but care must be taken not to wind too much on the roll, since it is much easier to add a little more than it is to take some off. This winding is removed, of course, when the fault has been corrected.

196. Wrinkles and Slack Places.—In cases where a straight wrinkle or lap appears in a new felt, and this often happens on wide machines (where the rolls are inclined to spring), run the felt slack and keep the wrinkle from running through the press by constantly pulling on the felt. But take care not to get caught in the rolls! Slack up the tail and tighten up the head of the wrinkle, by moving the guide roll or stretch roll. Hot sizing poured on the wrinkle will make it disappear almost instantly, if the sizing be not allowed to go through the press again.

Another trouble is the result of slack places and thin streaks or spots, which are due to excessive wear at certain points; these are frequently caused by accumulations of paper stock on a felt roll, which stretch the felt in spots the length of the felt, and the felt whipper wears these places thin.

197. Analogy between Felts and Belts.—It is readily perceived that the felt acts like a belt, and it drives many rolls that would be undriven otherwise; these rolls all act as brakes, and to their action must be added the braking action of suction boxes. It is also evident that the place of greatest stress and strain is close to the driver, where the sum of all the hold-backs is concentrated. This naturally brings up for consideration the matter of type of bearings and the kind of lubrication used on journals of main press rolls and of the felt rolls driven by the felt.

198. Lubricating and Cooling Journals.—The journals of press and couch rolls (unless ball bearing) are water cooled. The castings that hold the bearing metal are hollow, and cold water is circulated through them.

Many methods of lubricating paper-machine bearings are in use, ranging from the open-top bearing, with a piece of ham fat resting on the revolving journal, to the more pretentious bearings, which have a continuous supply of oil from a pump that may get out of order or from a reservoir that needs filling. Capillary bearings, which depend on a lamp wick to draw oil from a reservoir and wipe it on the journal, are also used with good results.

Paper-machine journals run at comparatively slow speeds; they should be amply large for the weights they support, and should have a cover over them, to keep out dirt and water and to keep in the oil or grease. A good millwright can often cure a bearing that gives trouble by cutting two helical grooves, say $\frac{1}{32}$ inch deep, on the journal, so as to compel the oil or grease to run around the journals until it reaches the place where the weight is carried. If the millwright is sufficiently experienced, he can tell where these grooves ought to be by examining the journals after they have begun to give trouble. Felt-roll bearings should have self-alining bronze bushings to line up with journals which are frequently bent.

199. While on the subject of bearings, it may be remarked that unless the paper machine is kept running all the time, and is making paper all the time, it is not making money. The cost of power to run it is but a drop in the bucket when compared with the value of the production lost through the shut-down of the machine for an hour or so a day; therefore, keep the bearings cool. A water-cooled bearing is simple and practicable.

200. Length of Felts and Number of Rolls.—Many mill men think a long felt is better than a short one; but, in most cases, this is far from being true. If additional rolls accompany the longer felt, there is no gain. For instance, a 45-foot felt running around 9 rolls is no better than a 35-foot felt running around 7 rolls; in fact, it is much worse, on account of the extra hold back of the two additional rolls, which evidently increases the total stress very near the driver. The life of a felt is materially increased by reducing the number of rolls that come in contact with the *outside* of the felt.

201. Pick-Up Felts.—If it is desired to have a felt pick up and carry away paper from another felt or from a wire, a smooth-surfaced felt that is air- and water-tight is needed. Such a felt must be woven of fine wool, and it should be napless; otherwise, it must be singed or sheared. A pick-up felt must be air-tight; therefore, it may be well filled with sizing. Trouble may often be experienced with a new pick-up felt; when this occurs, fill up the felt with sizing, which is poured on until the pores are filled, and the pick-up felt will then do its duty.

Owing to the attention now given by felt manufacturers to the requirements of paper manufacturers, and their mutual coopera-tion, the paper maker need only give the size of his felt and the quality of the product he is making.

202. Weight of Felts.—As to the weight of felts for different qualities of paper, there is very little information that can be accepted as a standard, because of the different ideas of various manufacturers of felts and paper. For instance, the weight of felts made by one manufacturer for a certain purpose might be quite different from the weight of felt made by another manu-facturer for identically the same purpose. One manufacturer of felts for news gets the best results from felts weighing 2 ounces per square foot; another manufacturer could not make a felt of this weight do the work satisfactorily, and had to make the weight of his felts 2.25 to 2.50 ounces per square foot. Similarly, for third-press felts for news, some manufacturers get the best results from felts that weigh 2.5 to 2.6 ounces per square foot, while others make their third-press felts weight 3 ounces or more per square foot. It is a question of durability and openness; given the same strength and durability, the lighter felt is more open and will give better results.

203. Qualities of Felts.—The first, second, and third felts for news and wrapping papers should have qualities about as follows, to obtain the best results:

First Felt.—The first felt should be of plain weave, made open, well napped, weight about 2 ounces per square foot, and should be *woven* endless—not made endless by hand, as has been common practice.

Second Felt.—The second felt should be the same as the first felt, except it should be somewhat heavier; weave like the first felt, but weight should be 2.25 ounces per square foot; this

felt should also be woven endless. After use on the first press, the first felt is sometimes used as a second felt; but if the nap is well worn, the paper may be marked.

THIRD FELT.—For the third felt, a fine twill-weave press felt should be used; weight should be 2.75 ounces per square foot; it should be well napped.

204. The Function of the Felt.[1]—When a felt and sheet of paper pass between rolls, the following conditions exist as shown in this diagram. Felt A and the wet sheet of paper B pass between the rolls M and N. As particular points, a and a' adjoining on sheet and felt, move into the nip of the rolls, a position b and b' is reached where water will begin to be squeezed
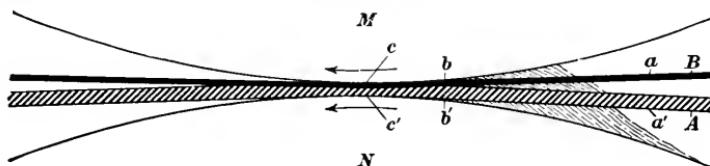
out of the paper and felt. From this point on, the pressure becomes more and more concentrated, felt and sheet are compressed closer together and water is released from both until c and c' is reached where the two rolls approach the closest to each other and the greatest concentration of pressure is obtained. It will be noted, then, that felt and sheet pass progressively through rapidly changing pressure, and that the condition of equilibrium of this system under a gradient of pressure distribution will be determined by the relations of many different factors such as—

    I. The pressure applied.
   II. Hardness of rolls.
 III. Radii of rolls.
 IV. The speed of the sheet and felt.
  V. The time of contact.
 VI. The resistance of the felt to the flow of water.

It will be seen in this diagram that the water passes from the sheet into the felt and through the felts throughout a gradient of pressure change. The ease with which water will flow through the felt at these different pressures is a very important factor in determining its efficiency as a water-remover. The openness or

[1] From an article, illustrated by charts, by E. A. Rees, in *Pulp and Paper Magazine of Canada*, Feb. 1, 1923.

porosity of the felt has always been recognized as a desirable property of the felt. And the resistance of the felt to the flow of water is important in determining not only the dryness of the sheet but also other effects that have to do with ease of operation, such as crushing and blowing.

It will be noted, however, that there are some discrepancies, as illustrated by several points that do not fall exactly on the line. The softness of the fabric also affects the concentration of the pressure upon the sheet of paper. Large variations in this property may so materially affect the concentration of pressure as to over-balance the porosity effect in different directions. For example, a hard, close felt might give a dryer sheet of paper than a soft, open felt, if the concentration of pressure is large enough to off-set the difference in porosity.

It is also quite interesting to note that as the sheet and felt approach closer to points c and c', where the rolls are in closer contact, there is more and more resistance to the flow of water, because of the impervious roll beneath; and there is also the tendency for the revolving roll to carry the water back into the nip. As the water is released farther back in the nip, then, there, is more and more necessity for water to permeate through the felt in the direction contrary to its motion. This lateral or backward porosity through a gradient of pressure change is also a factor in determining the efficiency of the felt as a water-remover.

205. Felts for Particular Papers.—When manufacturing fine writings and bonds, the character of the stock is such that it is difficult to free it from water. Here finish is the goal; hence, the felts are of decidedly closer texture and are made of finer yarns than the common wet felts used for newsprint or wrapping papers. While a newsprint felt is of a plain weave, the felts for fine papers are generally of a complex weave, the nature of which is to cause it to act as a compact carrier and as a perfect filler. A fair estimate of the weights per square foot for this grade is 1.46 to 1.64 ounces. The second felt will be heavier and much closer, weighing from 1.56 to 2.68 ounces per square foot. The felt for the last press, if three are used, is very thick and it has a very heavy nap. It must be borne in mind that the felt must permit a perfect filtering of the water from the sheet; otherwise, the cost of production will be high on account of the excessive steam consumption for drying.

The felt used on a machine making the general type of tissue papers is a plain-woven, rather close-mesh fabric, with little or no nap on the top side. In fact, many mills prefer that a felt for making tissue paper be singed on both sides, to keep the fibers in the sheet from adhering to the felt surface (picking up). Singeing keeps the nap that is formed by the felting process from being drawn over the mesh of the felt by the suction box or roll. If the under side of the mesh is clogged by wool, the felt will soon fill up and get dirty, causing broke and many other difficulties.

It is needless to state that the quality of the wool used in all these felts is a matter for the closest attention of the felt manufacturer.

DETAILS OF PRESS ROLLS

206. Construction of Press Rolls.—In the days when paper machines were so narrow that the attendant could almost reach across them, the lower press rolls were brass cased and the upper press rolls were made of wood. The nip, that is, the area of contact between the rolls, was very narrow, not only because of the absence of the resiliency and softness of the rubber covering but also because of the small diameter of the rolls. A little thought will make it obvious that the area of contact between two rolls of large diameter will be greater than when the rolls are of small diameter. Now the quantity of water pressed out of the paper is directly proportional to the pressure per square inch of area of contact between the rolls; in other words, the efficient working of a press is measured by the *specific pressure* of the rolls (total pressure divided by the area of contact) and not by the total pressure. Pressure is frequently expressed as so many pounds per inch of width of the machine.

The custom of covering the lower press rolls with rubber results from, first, the necessity for an automatic adjustment of the line of contact by an elastic medium, to correct for faulty crowning under differing conditions; also, second, to prolong the life of the felt.

207. Crowning the Roll.—Any beam will deflect (bend) more or less between its supports, because of its own weight; and the deflection will be increased by any other load that the beam may support. The amount of this deflection will depend upon the material of which the beam is made, the diameter of the beam (if round), and its length between supports. But there will be a certain amount of deflection always; and if the beam is straight

and horizontal, it will sag in the middle under its own weight and under a uniform load across the beam. A roll in a paper machine acts like a beam, and its own weight plus the pull exerted uniformly across it by the felt cause it to sag in the middle. It follows, then, when two rolls are ground to true cylindrical surfaces and are placed one on top of the other, both being horizontal (or nearly so) and supported at their ends (their journals), they will not touch at their middle points. This condition is proved by the fact that light passes between the rolls; and it can be corrected by crowning the lower roll (which naturally sags the most) just enough to insure perfect contact from end to end. A roll is said to be **crowned** when it is larger in diameter at the middle than at the ends and gradually tapers from the middle to the ends. The greater the diameter of the roll in proportion to its length the stiffer it is, and the smaller is the amount of sag (deflection); therefore there is but little need of crowning, if the roll be large enough.

But there are other considerations to be taken into account when choosing press rolls of large or small diameter for a paper machine. If the observer stand alongside a paper machine and note the escape of water at the nip of the press rolls, he will soon be impressed with the fact that the faster the machine runs the less chance the water has to escape, because the up-coming surface of the lower press roll continually tries to carry the water back into the nip; and the larger the diameter of the lower press roll the worse this condition becomes. Attempts have been made to place water deflectors close to the nip, to lead this water away, and in this service they have been invariably successful. In practice, unfortunately, many accidents have occurred through their use, such as the deflectors getting into the nip, etc., with the consequence that these deflectors are seldom, if ever used. If a press roll is made too small in diameter and is running at high speed, it is almost impossible for the machine tender to pick off the paper.

208. Effects of Rubber-Covered Rolls.—When the papers being made on the machine differ in weight and quality, the amount of pressure on the top roll is varied by shifting the weight on the levers that operate on the journals of the top roll. Since the amount of deflection of the roll varies directly as this pressure varies, the initial crowning of the rolls is not suited to every condition of working. The maximum efficient action of the

crown is possible only between comparatively narrow limits of variation in position of the weights. The use of rubber covering largely increases the limits of effective working pressure of a particular crown, as compared with the same crown on a similar roll that is not rubber covered. Unfortunately, the rubber, in adjusting itself to working conditions, largely increases the width of contact between the two rolls; this increases the area of contact and decreases the specific pressure, which lessens the de-watering action of the press. In brief, the rubber covering of a press roll corrects for faulty crown and preserves the felts; but it lets the paper go to the dryers containing a larger proportion of moisture than if a plain roll were used; and the softer the rubber the more pronounced is this last effect.

Although having greater de-watering power, hard rubber or metal rolls possess the following disadvantages: felt meshes fill and become hard much more quickly; this causes breaks at the press due to felt marks and to small lumps becoming crushed while passing through the press; causes loss of time, due to frequent washing of felts; and it shortens the life of the felt, because of frequent washing and the lack of cushion in hard-rubber covered rolls.

210. Felts taken from a press whose rolls are covered with hard rubber are seldom really worn out; rather, they have lost just enough of the nap to make them thinner and too hard to give good results with hard rolls; since thin, napless felts frequently mark the paper. Two weeks, or 12 running days of 24 hours each, is about the limit of running time for felts on hard rolls. Further, when hard rolls are used, it is necessary to wash felts at least once every 24 hours.

If rubber of the proper hardness (density) be used, the running time of felts between washings will be largely increased, and the life of the felts will therefore be greatly lengthened; in fact, felts may then be used for four or five weeks, or even longer.

If there is a disadvantage in using soft rolls, it is because they need more frequent grinding; a soft roll should be ground about once in every two months. However, a roll covered as stated will easily give 3 to 4 years' run, if properly used and not allowed to corrugate.

211. Troubles Peculiar to Rubber Coverings.—A rubber covering corrugates or gets uneven in lines parallel to the axis

of the roll, if the rubber is subjected to too much pressure. This effect is generally caused by the roll being crowned either too much or too little, and because the machine tender is obliged to carry too much weight on his levers in order to get an even pressure between the rolls across the machine. The longer life of a soft-rubber covered roll will more than counterbalance the expense of grinding the roll, when this is compared with the loss of felts and paper production that are inevitable consequences of the use of hard rolls. Hard rolls have also a further disadvantage, in that they have a decided tendency to check, and these *check marks*, or small cracks, must be ground out as often, nearly, as the soft roll requires grinding to remove its corrugations.

The density (hardness) of rubber-covered rolls that give satisfactory service should be measured with a plastometer, sclerometer, or a similar instrument; the results thus obtained should be noted and should be insisted upon when drawing up specifications for use in ordering new rolls.

Each maker indicates the density of his rubber covering differently; thus, one maker indicates the density for the first and second press rolls by $4\frac{3}{4}$ and for the third press by 5; another uses A.11 and A.3 for the same purpose; etc. The proper designations must be obtained from the makers' catalogs.

212. Crown of Rolls.—In general, it is probable that too much crown is given the lower roll, the elastic quality of the rubber covering being depended upon to counterbalance any irregularities in dressing the roll.

The following table gives, approximately, the proper crown for lower press rolls when they are being ground; and the values here specified are sufficiently exact for all practical purposes, unless the design of the roll itself varies extremely from general shop practice. The table gives the crowning for rubber-covered rolls for the first and second press; for the third press, reduce the values 5%. Thus, for a 20-inch roll for a first or second press having 180 inches length of face, the crowning is (see table) .104 inches; for a third press, this should be .104 $\times$ (1 − .05) = .104 $\times$ .95 = .0988, say .099 inches. The figures here given for the crowning indicate how much larger the diameter of the roll should be at the middle than at the ends. It is assumed that the rolls are made with cast-iron bodies and that they are of standard construction.

CROWNING OF STANDARD PRESS ROLLS IN THOUSANDTHS OF AN INCH

Diameter in inches	Face of roll in inches																							
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250
6	6	19	43	78	132	210																		
8	3	8	18	33	55	90	140	200																
10	1	4	9	17	30	47	72	102	140	180	236													
12	1	2	5	10	17	27	42	59	81	105	137	175	215											
14		1	4	7	11	17	26	37	51	66	86	110	137	168	206									
16		1	3	5	8	12	18	26	36	46	60	77	96	118	144	172	202							
18		1	2	4	6	9	13	18	25	31	43	54	67	83	101	121	143	169	197	228				
20			1	3	4	6	9	13	18	24	31	39	49	60	73	87	104	122	142	165	189	217		
22			1	1	3	5	7	10	14	19	24	30	37	46	56	67	79	94	110	127	145	166	190	215
24				1	3	4	6	8	11	15	19	24	30	37	45	54	64	75	87	100	114	128	146	165
26				1	2	3	4	6	9	12	15	19	23	31	37	44	51	60	70	81	93	107	122	138
28					1	2	3	5	7	9	12	15	19	23	28	33	40	47	55	64	73	83	96	108
30					1	2	3	4	6	7	10	12	15	19	23	27	32	38	44	51	59	68	77	87
32						1	2	3	5	6	8	10	12	16	19	22	26	31	36	42	48	55	68	77
34						1	2	3	4	5	6	8	10	13	16	18	22	26	30	35	40	46	52	59
36							1	2	3	4	5	7	8	11	14	16	19	22	25	29	33	38	42	49

THE FELT ROLLS

213. Construction and Sizes.—The shells of the felt rolls should be of such quality and thickness that, for any specified diameter, they may have sufficient strength to withstand the strains induced by the continuous reversal of stress, which is due to the turning of the roll in the grip of the pulling felt. Consider, for instance, a felt roll 8 inches in diameter, to be used on a high-speed news machine. Such a roll may revolve on its own axis say 300 times in a minute, giving 600 reversals of stress in that time. Some day, this action must crystallize the metal at the point of greatest bending moment, just as a wire can be broken by continually bending it back and forth. The life of these rolls depends on the selection of good material, proper thickness and diameter of shell, and they should be in dynamic balance. Use as few rolls as possible on the outside of the felt; each is a dirt catcher, and each deposits dirt on the paper side of the felt.

214. Proper Balancing of Rolls.—A roll is in **static balance** (neutral equilibrium) when it can be placed with its axis horizontal, its journals resting on knife edges, and have no tendency to roll or turn. A roll is in **dynamic balance** when it turns
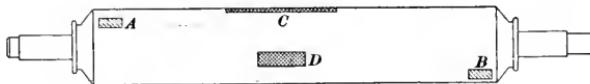
Fig. 62.

steadily in its bearings at high speed. A roll may be in static balance and not in dynamic balance, as will now be explained. Referring to Fig. 62, suppose A, B, C, and D are weights placed inside the shell. If A and B are equal in weight and shape, are situated equally distant from the axis of the roll, are placed on opposite sides, but at opposite ends, the roll will be in static balance. If C and D are of different weights and shapes, C being lighter than D and farther from the axis, D may be so placed that the roll will still be in static balance. If the roll is turning swiftly in its bearings, weights A and B not being directly opposite each other will impart to the roll a wobbly motion. Since C and D are not of equal weight and are situated at unequal distances from the axis of revolution, the centrifugal force exerted by D and the section of the shell adjacent to D is not quite the same as that exerted by C and the section of the shell adjacent to C. At very high speeds, the difference between these two values

for centrifugal force becomes considerable, and it puts additional stresses and strains on the roll and on the bearings. This matter of dynamic balance becomes especially important in connection with Fourdrinier table rolls.

THE DRAW

215. Definition of Draw.—At this point, it is advisable to consider the effect of faulty draws of paper between the presses. The **draw** is the pulling the paper receives as it passes from one pair of rolls to another; for example, between couch rolls and the first press rolls, between the rolls of the first and second presses, the second and third presses, last press and dryers, dryers and calender, and calender and reels. The term is especially applicable to the gaps at the wet end, where the paper gets about all of its longitudinal stretching, which is caused by each press running faster than the one that precedes it.

216. Correcting Faulty Draws.—If the paper is too tight between the couch rolls and the first press, and between the presses, it may get narrow, even though the deckles have not been moved, and the trim at the slitters may be getting dangerously narrow. In such cases, bring the various presses more nearly to a uniform speed by speeding up the slow ones or slowing down the fast ones. The trouble may have arisen through changing the weights on one press, or because of a change in character of stock. Many paper makers are too afraid of a slack draw between presses; a slack draw is a good thing, provided it is not loose enough to crease the paper. Always remember that the less a paper is stretched on the machine the stronger it is. The control of the draw has been improved by the development of the electric drive, described in Vol. V.

Sometimes a paper machine is not quite in alinement, and the paper may show a tendency to travel to one side, even arriving at the calenders 4 inches or more to one side. This fault can be corrected by putting a leading roll with the proper "cant," obliqueness, between the last press and the dryers, thus guiding the paper back again to the center of the dryer rolls.

217. A Cause of Winder Trouble.—A great deal of the trouble experienced with calenders and winders on high-speed machines is due to faults at the press part. Failure to press the paper to a uniform thickness is especially liable to cause trouble on the uniform speed reels and winders.

PAPER-MAKING MACHINES

(PART 2)

EXAMINATION QUESTIONS

(1) Explain how the paper is transferred from the wire to the felt.

(2) What factors affect the percentage of solids in the paper as it comes to the press part?

(3) What factors affect the percentage of solids in paper going from the press part?

(4) About what is the limiting percentage of solids obtainable in paper by pressing in the press part of the paper machine?

(5) (*a*) What is the nature and purpose of the press-roll doctor? Why should it be oscillated?

(6) (*a*) How is the paper transferred from the first press to the second? (*b*) from the last press to the dryers?

(7) Why is the paper reversed at the last press?

(8) Explain the purpose and operation of the felt guide roll?

(9) (*a*) Describe a felt suction box? (*b*) What is the advantage of using it?

(10) A press has the following lever system?

(11) Name some advantages of a suction press roll.

(12) Describe the method of putting on a new felt.

(13) What precautions should be taken when putting on a felt?

(14) (*a*) What is usually meant by "felt mark"? (*b*) how is it remedied?

(15) Mention some points on the care of felts.

(16) What is the effect of tension on felts?

(17) What is meant by crowning a roll? Why is it necessary? How much crown is required for a roll 160 inches wide and 24 inches in diameter.?

(18) What is the effect of incorrect crown of the press roll on the felt?

(19) Compare the effects of small hard- and soft-rubber rolls.

(20) Explain (a) the term "draw;" (b) the danger in a slack draw; (c) in a tight draw.

SECTION 6

PAPER-MAKING MACHINES

(PART 3)

THE DRYER PART

SMOOTHING ROLLS

218. Passing from Last Press to Dryers.—The paper has now been followed from the breast roll of the Fourdrinier part until it has passed, with its direction reversed, through the nip of the last press of the press part. The paper has been picked off by the machine tender and passed over the paper roll, which is carried by brackets on top of the last part of the press rolls. This part, like all other paper rolls, unless driven, must be set in motion before the paper is passed over it. From this point, the paper is put through the smoothing press; or, if there is no smoothing press, the paper is passed directly into the *dryer section, dryer part* or *dryer nest*, as it is variously termed. But if the last press be not reversed, the paper comes straight through with the felt, and it can be passed directly to the smoothing press or dryers.

The paper at this point will contain 60% to 70% of water. In this condition, it requires less pressure to smooth out the inequalities in the surface that are due to impressions of the wire mesh and the weave of the felts than when the paper is dry and hard. It is also possible to print what is practically a watermark by impressing steel type on the soft paper. Other designs may be produced in a similar manner. In some papers, the impressions of the felt and the bulk of the sheet are to be retained for special effects; but this can be secured and the paper flattened to a uniform thickness, by means of a properly adjusted pair of

smoothing rolls, no felt being used between these rolls.   When the paper is finished at the calenders, there is a greater likelihood of injuring the fibers.   Calender finishing depends more on friction for its results, and the weight on the paper is enormously greater.   The smoothing press is most applicable to the making of book papers.

219. The Smoothing Rolls.—Fig. 63 shows a pair of smoothing rolls, A and B, which are mounted on the dryer frame at the end nearest the last press rolls K of the press part.   The top press roll A is rubber covered, while the lower press roll B has a gun-
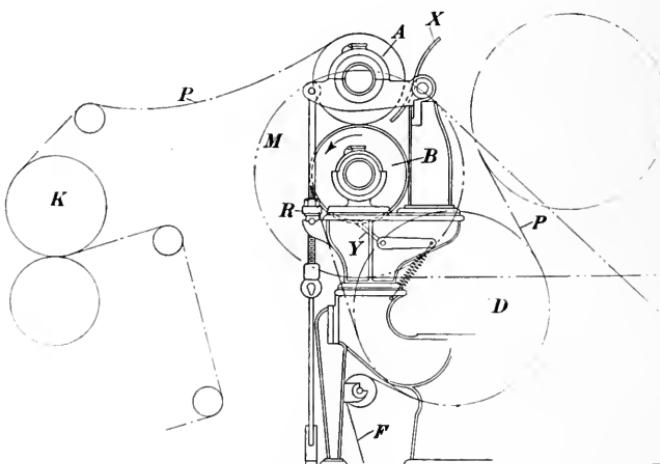
FIG. 63.

metal or bronze shell.   These rolls may be so made that they can be reversed; that is, the rubber-covered roll can be placed on the bottom and the metal-covered roll on the top.   Some paper makers prefer to have the rolls interchangeable with the brass and rubber rolls, respectively, of the wet press.   It should be noted that wood (maple) and stone rolls may also be used. The required difference in hardness may also be obtained by using two rubber rolls of different degrees of hardness.   The paper P is shown as passing over the top of the upper roll, back through the nip between the two rolls, and from there to the first lower dryer D, against which it is held by the dryer felt F.

Attention is called to the ductor X, which guides the paper into the nip of the smoothing press; also, to the doctor Y, which scrapes the paper off the lower smoothing roll, so it will drop

between the dryer felt and the first lower dryer D. If desired, the paper can be passed directly from the last press K through the nip between the two smoothing rolls.

Each succeeding unit of the paper machine runs a little faster than the preceding one, to prevent the paper from running back on a roll and catching on a doctor. This causes a *draw* (see Art. **215,** Part 2) between successive units, which requires careful attention and is a frequent cause of breaks. Adjustment is made by shifting a belt on a cone gear of a mechanical drive, etc., or by means to be described later in connection with an electrical drive.

220. Crowning the Roll.—The rubber roll is compressible and resilient, thus assuring a perfect contact across the machine, if accurately crowned and covered with rubber of the proper density. The correct crowns to be used as a guide in grinding these rolls have been given in Part 2 of this Section. Since the design of a press roll varies in accordance with the ideas of different paper-machine manufacturers, the crowns there specified may not quite suit all makes of rolls; but, for the first grinding, they are accurate enough to work satisfactorily within the range of control given by the weights and levers.

By carefully studying the smoothing press and its functions as here described, the machine tender can form his own opinion, in any particular case, as to whether it is better to pass the paper over the top roll or directly through the nip, and whether to have the rubber or the bronze roll on top; either change reverses the side of the sheet in contact with the rubber roll. In deciding such matters, always take into account the matter of risk of injury to the man that passes the paper, and use that arrangement which will be the safer for him.

221. Finish of Paper.—The whole question of finish of paper can be solved by straight thinking. First find out what finish is required, whether it is to be rough, smooth, or glazed. A **glazed finish** is obtained by crushing the surface of dry paper after a superficial dampening or sweating; a **smooth finish,** by the use of pressure rolls or breaker calenders in the dryer nest. M. G. or machine glazed paper is made on a Yankee machine, which is fully described in Vol. V.

222. Adjusting the Pressure.—A method of adjusting the pressure between the rolls, one that is used quite generally on

smoothing-press installations, is shown in Fig. 63. At R, a stationary revolving nut, which is usually turned by means of a ratchet handle, is used to bring the two rolls together. One of the rolls is covered with chalk and is brought into contact with the other roll by means of the two ratchets, one on either side of the machine, until no light can be seen between them; the rolls are then separated, and the width of the chalk mark that is impressed on the unchalked roll, preferably the rubber roll, will show by its character, whether even or uneven, the degree of pressure between the rolls with respect to uniformity. If the position of the weights and the position of the screws with respect to the ratchets be plainly marked by center-punch or chisel marks when the transferred chalk mark is even all the way across the machine, then this machine can be easily adjusted when running to give uniform pressure when doing its work as a smoothing press.

223. Definition.—There is sometimes a misunderstanding as to the meaning of the words "ductor" and "doctor," as used in the industry. In this textbook, the term **ductor** refers to any device for leading (conducting) the paper into a nip. The word **doctor,** on the other hand, refers to a scraper that is used to keep the surface of a roll clean.

A TYPICAL DRYER PART

224. Purpose of the Dryers.—The **dryer section** of a paper machine consists of a set of cast-iron cylinders, connected and driven by a train of gears, and heated by steam, the steam so used being exhaust or low-pressure steam. Most machines have a dryer felt or canvas, to support and carry the paper and hold it in contact with the cylinders, which are usually called the **dryers.** Heat from the steam is conducted through the dryer shells to the paper and evaporates the moisture (water) in the paper; the resulting vapor is absorbed by an air current, and is carried outside the building. In passing over the dryers, the moisture content of the paper will be reduced from an original state of 60%–70% to 6%–8% on leaving the dryers; this means the removal of about 2 pounds of water per pound of finished paper.

It is necessary to provide means for removing the moisture-laden air from the room and, also, for removing from the dryers the water that results from the condensation of the steam; methods for accomplishing this will be described later.

225. The Two Parts of the Dryer Section.—Fig. 64 shows a typical dryer part. It consists of a smoothing press A, 30 48-inch (diameter) dryers D, and 2 36-inch felt dryers B. In this case, the paper passes through the smoothing press, and the dryers are driven by gears at the back. There are two upper felts and two lower felts. The first upper felt and the first lower felt partially enwrap the first 8 (left-hand) upper dryers and the first 8 lower dryers, respectively. The first upper felt and first lower felt have each a felt dryer B, an automatic guide roll C (see also Fig. 66), and an automatic stretch roll E (see also Fig. 67). The second upper felt and the second lower felt partially enwrap the 7 upper dryers and the 7 lower dryers, respectively, at the right end of the nest (section); they both have an automatic guide roll G and an automatic stretcher F, but no felt dryer. The felt on the first-felt dryer is more efficiently placed as shown, because the dryer felts are damper at this point than at any other place in the dryer nest, and the dried felt immediately takes up paper again. The reader is advised to take a pointer that will not mark the diagram, Fig. 64, (a knitting needle will do), and follow, first, the run of the felts throughout the nest; then follow, second, the run of the paper. Follow the run of the felts first, beginning with the lower felt, because it first receives the paper. The circles in solid lines represent dryers, the larger ones in dotted lines are the gears.

Fig. 64.

226. Course of the Felts.—Beginning with the felt roll H, below the smoothing press, follow the lower felt throughout its entire length
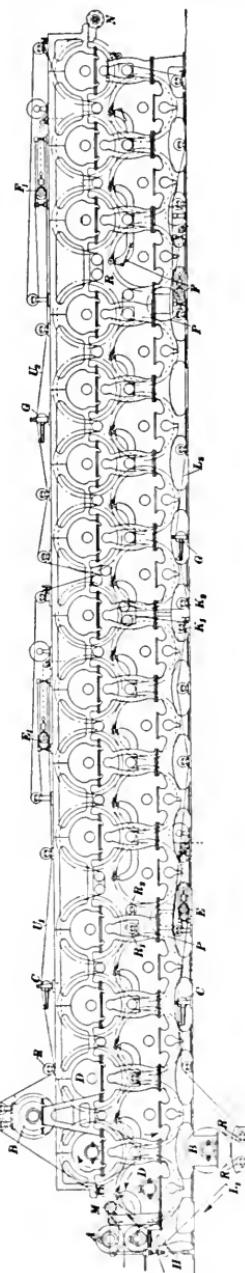
until the starting point is again reached. This felt (canvas wraps around approximately one-third of the circumference of the first (left-hand) dryer D. The felt touches about one-half of the surface of each dryer after the first; it passes under the first four dryers and over the first four felt rolls (not counting the first roll H), reaching at this point the two rolls R_1 and R_2, over the pinion P. As the felt comes up from under the eighth lower dryer, over the felt roll, and down on its return journey, it first passes around a hand guide roll K_1. This last is simply a felt roll, one journal of which rests in bearings on a bracket, which can be moved by means of a hand screw; the hand screw itself is fixed, and it works in a bracket base, as in a nut, to move the bracket in the desired direction. The hand guide roll may be located elsewhere; in fact, it is a principle that the lead of a felt to a guide roll should be as long as possible.

The dryer felt then travels back until it comes to the automatic stretcher E, which is more fully described later. This stretcher automatically takes in the slack of the dryer felt by means of weights, which are suspended on a carriage, the chain holding the weights passing over a pulley that is between the stretcher and the weights. The position in which the stretcher is here shown is probably due to some local condition or some personal idea of the designer; it were better to place it nearer the hand guide roll or nearer the first return of the felt, like the stretchers shown at E_1 and F_1 in the two upper felts, and at F in the second lower felt.

From the automatic stretcher, the felt passes over an automatic guide roll C, which is more fully described later. This guide roll has bearings on brackets that swing on pivoted levers. When the felt travels too much to one side, it pushes against a finger on the lever at that side, which pushes the bearing forward and forces the felt to travel toward the other side. To obtain sensitive automatic action of the guide, the distance between the nearest roll back of the guide roll and the guide roll itself should be at least 6 feet, and preferably much greater, the best distance being determined by local conditions.

After leaving the automatic guide roll, the felt comes to the **felt dryer** B. Concerning the value of a felt dryer, there is a difference of opinion. Insofar as drying the paper goes, a felt dryer is probably not the equal of an extra dryer in the dryer section; but drying the felt is supposed to keep the felt from rotting, and it thus makes the felt last longer.

In the manner just outlined, the reader is advised to follow the course of the other three felts. Some machines have only one lower and one upper felt; some have no upper felt, but if the dryer nest be driven as two parts, the felt must be divided.

227. Prevention of Accidents.—The felt roll *H* under the smoothing press is so placed that the paper from the smoothing press can be easily dropped between the felt and the first lower dryer without any danger of crippling the back tender's hands. A pony dryer or lead roll is often used, and occupies the position of the smoothing press. Too much stress cannot be laid on the necessity for extreme care, not only in passing the paper through the dryers but also in considering and selecting the best position for the dryer-felt rolls between the dryers. The danger points are where the back tender is required to pass the paper in between the felt and dryer, when both felt and dryer surfaces are moving so as to draw the hand in; the points where the paper is to be taken out are obviously less dangerous. It is a good thing to move all the felt rolls over as far as practicable, to make the receiving angle as wide as possible. No point of machine efficiency should be considered important enough to warrant the increase of any risk to the operator, beyond the absolute minimum obtainable.

228. Some Troubles and Their Remedies.—Troubles on a machine can sometimes be remedied by increasing the lead between the felt roll and the guide roll in the direction in which the felt is traveling. If the felt is getting wet after passing the automatic stretcher, and there is a felt dryer on that felt, take some weights off the automatic stretcher, thus avoiding the strain due to any subsequent shrinking.

A felt dryer that is situated as in Fig. 64, will tend to cause the felt to pull very strongly on the nearest felt rolls. If the felt gets wetted by vapors after it leaves the automatic stretcher, and before it reaches the felt dryer, the pull may be so great as to bend the rolls slightly.

The reader is advised to follow the course of the other three felts shown in Fig. 64 in a manner similar to that just described for the first lower felt.

229. Course of the Paper.—The course of the paper will now be followed from the smoothing press to the spring roll *N*, around which it passes before entering the calenders. As the paper leaves the smoothing press, it is dropped between the felt and

the first lower dryer D, Fig. 64, passes under the dryer, comes up on the other side, and a little wad is tucked between the felt and the first upper dryer.   After passing the first upper dryer, it is taken by the back tender and passed to the entering side of the second lower dryer; it is thus passed under each lower dryer and up over the next succeeding upper dryer until it leaves the last upper dryer and is thrown up into the top nip of the calenders; sometimes it is thrown over the top roll, depending on which side of the stack the first nip is.   The spring roll N automatically takes care of variations in tension.   The reader should follow the course of the paper on Fig. 64, from one end of the dryer nest to the other.

A very helpful device for taking the tail over the dryers is the Sheahan **rope carrier.**   This consists of a pair of endless ropes that are carried in grooves on the front ends of the dryer surface. They travel close together, except where they are made to approach each other at the first dryer so as to grip the end of the tail placed between them.   The back tender follows the paper along, so as to pass it by hand in case of a break.   In another patented device, compressed air is used to pass the paper from dryer to dryer, and from the last dryer to the calenders.

Doctors are sometimes used on dryers to prevent the paper from winding round them.

230. Steam Joints and Driving Gear.—Fig. 65 is a cross-sectional view of the dryer nest shown in Fig. 64.   The felt rolls R, the felt dryers B, the top and bottom dryers D, D, all have the same reference letters as the corresponding parts in Fig. 64. The steam joints M, shown connected to the back hollow journals J of the dryers, are piped to two pipe headers S and E.   The larger pipe S supplies steam to the dryer, while the smaller pipe E is a drain that carries away the water of condensation.   The steam joints are described later.

The gears that drive the dryers are shown at G, and a platform or walkway for the operators is shown at K.   In this case, the felt dryers B are driven by the felt, and they have no gears; this is good practice, but the bearings must be kept in first-class condition.

231. Dryers to Be Kept Free from Water, Air and Grease.—It is essential, in order to dry paper well and evenly all over, that the dryers be kept free from water, air, and grease.   An air valve

on the front head of the dryer, which may be a small pet cock, will prevent accumulation of air, if opened at intervals. The air acts as a blanket, to prevent heat getting to the dryer shell. The water that collects in the dryer, because of the condensation of the steam, is emptied by either a siphon or a dipper, as will be
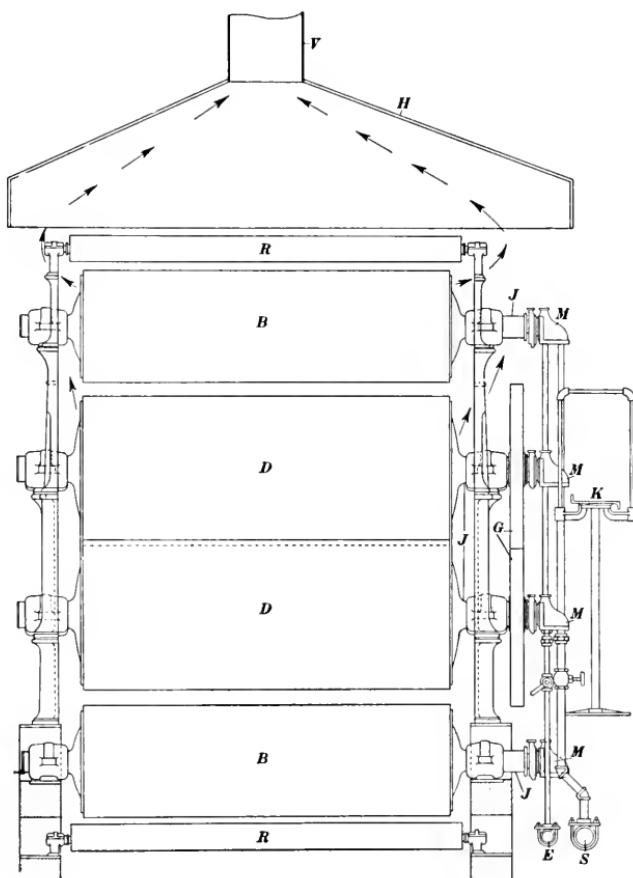
Fig. 65.

described later. Some heating systems are designed to sweep the air out of the dryers by circulation of steam.

The dryer part should be started turning over before any steam is admitted into the dryers, in order to prevent the unequal strains that are produced when hot steam enters a cold dryer that contains a body of cold water in its bottom; in such a case,

the top of the dryer heats and expands more than the bottom, and thus tends to get out of shape.

Oil acts as a coating, on the inside of the dryer, preventing transfer of heat; it may get into the steam from the lubrication of the engine piston and should be caught in an oil separator. If it gets into the dryer, it may be removed by treatment with a hot solution of soda ash.

DETAILS OF DRYER PART

GUIDING THE FELT

232. General Principle.—On all carrying rolls, the felt will come to the side that the felt touches first, regardless of whether the roll be inside or outside of the felt. If one end of any roll be moved toward the direction of travel of the felt, the felt will come toward the end so moved; except, that if the moving of the end of the roll causes the roll to stop or causes its speed to slacken until the speed of the roll is slower than that of the felt, the felt will then slide the other way. All guide rolls should be provided with a swivel box on the end opposite the end of the roll moved. Ordinary carrying rolls should not be moved very far out of alinement.

233. Automatic Guide for Dryer Felts.—A typical design for an automatic guide for dryer felts is shown in Fig. 66. The felt on its way from the felt roll R passes under the rod S and over and between the two fingers F, F. These fingers are attached to the rod S by small clamps and bolts, as shown, and can be moved along this rod in order to adjust the distance between them to suit different widths of felts. When the felt is running straight and the fingers are properly spaced, about $\frac{1}{2}$ inch farther apart than the width of the felt, the outside edges of the felt will not touch the inside of the fingers, but will pass through freely. The fingers hang downwards, as shown in view (b), and they are of sufficient length to partly support the felt as it passes over them. When the felt begins to travel out of line, it will touch and push against one of the fingers, say at a, view (b), and this will cause one end of the bell-crank lever KL to move. This lever turns easily on the pointed pivots P, which are supported by the brackets B. The arms L carry the bearings E for the

ends of the felt roll on which the felt travels. The arms K are connected by the cross shaft S; hence, in the case of the felt traveling toward either side, the felt roll is moved by this action, one journal of the roll being advanced and the other being pulled back, in proportion to the effort made by the felt to get out of line. A roll always tends to move any body touching it in a line perpendicular to its axis; consequently, the automatic stretch roll here described acts to force the felt to correct its own errors of travel and keep it in line. It will be noticed that the journal
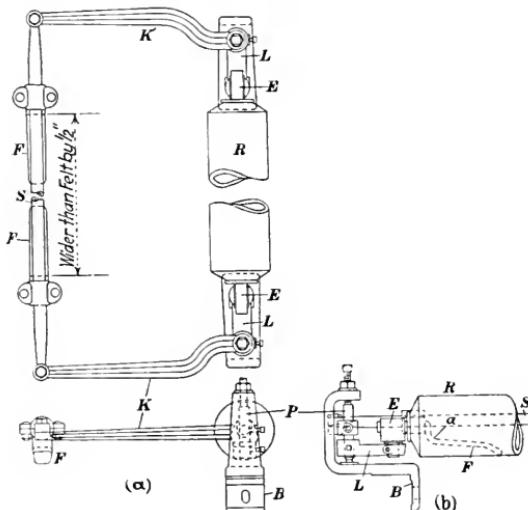
FIG. 66.

of the guide roll that is on the side toward which the felt is traveling is always *advanced*, while the journal on the other side of the machine is simultaneously pulled back. As the result of this action, the guide roll is quickly shifted by the felt when it runs out of line, and in such a manner that the axis of the roll is thereby made perpendicular to the direction the felt must travel to correct its own error.

STRETCHING AND TIGHTENING FELTS

234. Automatic Stretcher for Dryer Felts.—An automatic dryer-felt stretcher is shown in Fig. 67. The felt F is wrapped half way around a felt roll R, whose journal runs in a bearing that is carried by trolley wheels C, a similar journal, bearing, etc.

being on the other end of the roll. The trolleys C on either side
of the machine are caused to move simultaneously by the shaft S,
which extends across the machine. Therefore, when pulleys A
and B on one side turn, the corresponding pulleys on the other
side turn also; and they turn the same distance at the same time,
because all these pulleys are keyed to the shaft S. This device
keeps one end of the stretcher roll from being pulled ahead of the
other, and thus shifting the felt.

The weights W, which are hung on chains D that grip the chain
slots on pulleys A on both sides of the machine, tend to turn
shaft S with a force that is proportional to the number of weights
hung on these chains; and they are generally so calculated as to
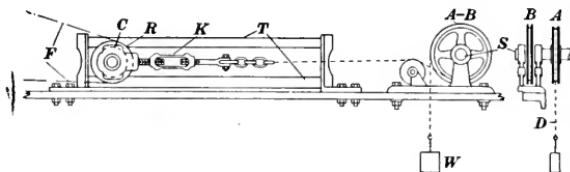
Fig. 67.

give a pull of about 2 pounds per inch of width of felt. The pull
of the weights on pulleys A tends to turn shaft S, and also pulleys
B, which are at the ends of the shaft in line with the trolleys C.
The chains on the trolleys are furnished with turn buckles K, to
permit of accurate adjustment. The chains are also attached
to the rims of pulleys B; so that, as these pulleys tend to turn,
the chains pull on trolleys C and, therefore, on the felt that is
wrapped around the felt roll carried by trolleys C. The trolleys
move easily on the guide rails T; and when the pull of the felt
slackens, the weights automatically pull on the trolleys until the
proper tension is obtained.

235. Felts Should not be too Tight or too Loose.—The machine
tender should form the habit of watching the automatic felt
tightener, to observe its condition; if in good condition, this will
be indicated by a constant movement in one direction or the
other. If the tightener always remain still, it should be examined;
it is then probably out of order and may require lubricating, or it
may be gripped between the rails, or the chains may have slipped
off the pulleys. If the automatic stretch roll does not work
properly, report it to the millwright. A felt that is too tight or
too loose will spoil paper very quickly, causing uneven drying and

cockling; since the felt rolls may be pulled out of line, if the felt is too tight, or the felt may be hanging loose because the slack is not being taken up.

The old-fashioned felt tightener did not have sufficient capacity to take up all the slack in a long felt. This type of stretcher is still used on dryer felts, and it will take up a certain amount of slack; but it is necessary to install also a hand-stretching device that is similar in design to the hand felt stretcher.

236. The Dancing Roll.—A very sensitive and direct-acting stretcher for a dryer felt is a **dancing roll**; this rests in a loop of the felt, the entire weight being carried by the felt. Brackets are bolted to the dryer frames, and the bearings of the roll are free to move up and down the vertical slots in the brackets. The "return" felt rolls, over which the felt runs to make the loop, are supported in brackets bolted to the slotted brackets. This is a good type of dryer-felt stretcher; its principal failing is that it is limited in its range of action by the height of the vertical slots in the brackets. Another drawback is that one end may get into a higher position than the other, which would cause the roll to act like a guide roll and shift the felt to one side of the machine.

237. Amount of Stretching and Shrinking.—The purpose of the automatic stretcher is to take up the slack of the felt when the paper leaves the machine for any cause, as a break at the wet end or a shut down. A 60-yard felt will shrink 3 feet at the very least when it is wet, and it lengthens a like amount in a few minutes, when the paper is off the dryers. On the average, a brand new felt will shrink and stretch considerably more than this, some felts as much as 6 feet. The old-style swing stretcher did not give enough leeway to take care of this shrinkage; and if the felt were tightened up sufficiently to run straight and guide properly, it was too tight when it became wet.

After putting on a new felt, it should be weighted down until it is fairly tight; and it should be run around a few minutes before passing the paper over it, to let the felt straighten. After the felt is perfectly straight and the paper is passed over the machine, the machine tender should watch the automatic stretcher, to see that it is easing up as the felt gets shorter. If the felt is getting crooked, it is a sign that there are not enough weights, for a slack felt will almost always run crooked. When a good automatic stretcher is in proper working order and is well adjusted, the

stretch roll should tremble—move back and forth slightly—
every time the dryer-felt seam passes over it.

238. Guiding Felts by the Stretch Roll.—Some stretchers
stretch with the felt, *i.e.*, move in the direction of travel of the
felt; others move in the opposite direction.

To show how the stretch roll may be used to guide the felt,
consider Fig. 68, in which either A or B may be the stretch roll; if
A be the stretch roll, then B is the reef, or fixed, roll, and *vice*
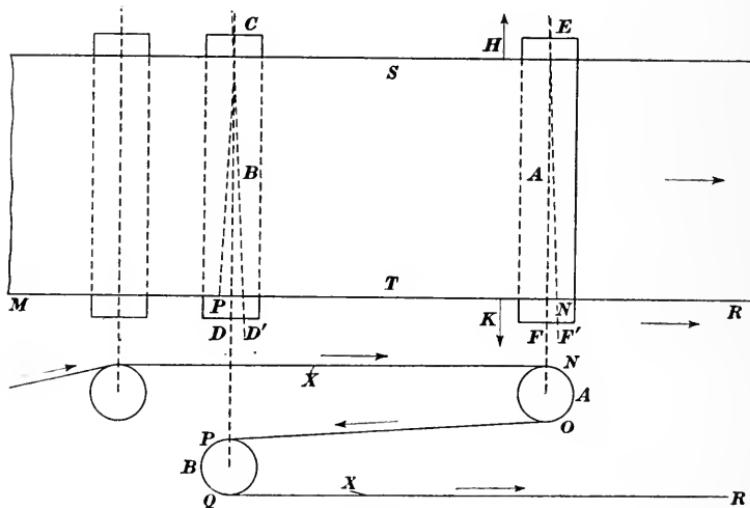
FIG. 68.

versa. Suppose the felt to be traveling in the direction indicated
by the arrows, that T is the tight side, and that S is the slack side.
If, now, the roll A be shifted toward the tight side, so its axis
EF makes an angle FEF' with its former position, the felt will
go to the slack side, in the direction of the arrow H; but if B be
shifted toward the tight side, so its axis CD makes an angle DCD'
with its former position, the felt will go to the tight side in the
direction of the arrow K.   The roll A acts just like the carrying
rolls mentioned in Art. **232**, while B checks in the opposite
direction.   The felt traveling from the under side of A to B
does not count in this connection.

The dryer-felt stretcher is one of the most important parts of
the machine to know how to handle.   If, for any reason, the felt
gets beyond control and gets partly off the machine, moving

the stretcher 2 inches out of line will guide the felt more quickly and surely than all the carrying rolls together.

The wet felts or woolen felts will always go to the slack side of the stretcher, except, very rarely, in the case of a new felt, which may go to the tight side for a few hours.

Dryer canvas felts are not made endless. Wool dryer felts, sometimes used on very fine paper, are made endless. Many European machines use endless, wool dryer felts.

REMOVING AIR AND WATER FROM DRYERS

239. Necessity for Removing Water.—It was stated in Arts. **224** and **231** that the steam in the dryers is continually condensing into water as the paper passes over the dryers. The water that collects in the dryers must be removed, since the presence of even a small quantity of water prevents the quick and uniform drying of the paper. Two methods are employed for getting rid of this water: in one, dippers or scoops are attached to the dryer and turn over and around with it, scooping up the water to the center, from whence it flows out of the hollow journal; in the other, a siphon, which remains stationary and dips down to the bottom of the dryer, is used.

240. Dippers.—Both dippers and siphons require some form of stuffing box or steam joint on the end of the journal, to admit steam into the dryer and let out water without loss of steam or leakage of water.

Fig. 69 shows a dryer fitted with a steam joint, a double dipper, and an interior steam distributing pipe P, which is so perforated that the entering steam is distributed to all parts of the dryer. The two dippers D are formed of open channel irons, of such a shape and bolted to the dryer head H in such a manner, that they scoop up the contained water, when the dryer revolves in the direction indicated by the arrow. The water enters the open end of the scoops; and, as they are raised by the turning of the dryer, the water that is scooped up flows along the channel and is dumped into the receiving chamber C. This chamber is a cast-iron receptacle, so equipped with baffles and guides inside as to guide the in-coming water in such a way that it is forced out between the inside of the rear journal J and the outside of the steam pipe P. When the water reaches the steam joint, it flows

out through passages E into the pipe W, and from thence on to the main drain pipe below.   In the front head is a manhole M; T is a pet cock, which allows the escape of air when starting up, and breaks the vacuum when shutting down over Sunday.   Air is a good non-conductor of heat; and if it be not removed, it will make a blanket next the inside of the shell and prevent efficient transfer of heat and drying of the paper.   The air vent is sometimes put in the cap of the front journal K, which is then drilled through.
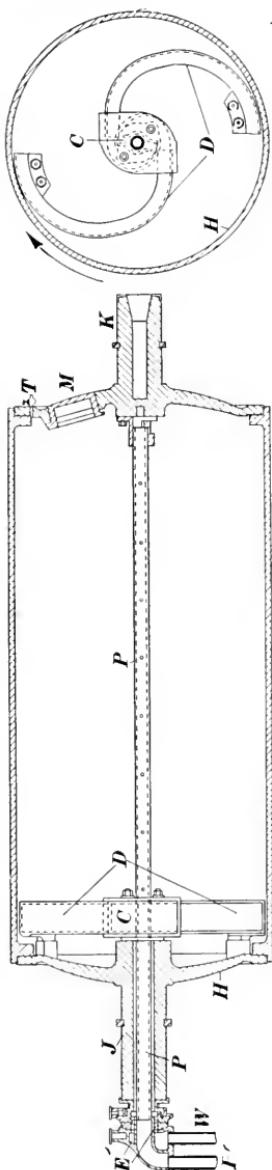
241.   Another type of dipper extends in sections across the dryer, and is attached to the dryer shell.   Its operation can be compared with the action of scooping up water in a dustpan and raising it until the water runs down the handle and into one's sleeve, the sleeve corresponding to a pipe that carries the water off.   The pipe that receives the water from the scoop is horizontal; it extends through the center of the dryer, and it conducts the water to the steam joint.   It is obvious that a dipper cannot work when the dryer is stationary; but the steam continues to condense, whether the dryer is stationary or not.

242. Siphons.—One end of a dryer F is shown in Fig. 70; it is equipped with a siphon K_1.   The steam inlet is shown at H; K is the water (condensed steam) outlet, and G is the stuffing box and steam joint.   As before stated, the siphon remains stationary while the dryer revolves.   The lower end of the siphon pipe must clear the bottom of the dryer at least half an inch, in order to make certain that the dryer clear

Fig. 69.

the pipe as it turns; this keeps foreign substances from collecting
and catching the siphon pipe, thus forcing it to turn with the
dryer. Sometimes the pipe is carried around and left sticking
up instead of down. The siphon pipe here shown is not of good
design, because the sharp bend in it does not allow of the pipe
being put in or pulled out through the journal. A longer pipe,
one that reaches nearly to the other end of the dryer in a long,
gentle curve, could be inserted and withdrawn readily, and with-
out removing the head.
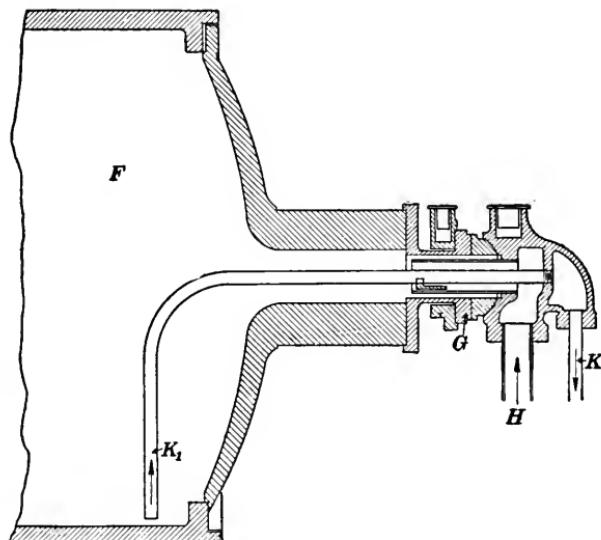
FIG. 70.

When the bottom end of the siphon is covered with water, the
higher pressure in the dryer is exerted on the surface of the water,
forcing it up through the siphon and out through the hollow
journal.

243. Comparison of Dippers and Siphons.—There is a great
diversity of opinion as to the relative merits of siphons and
dippers. It is a matter of fact, however, that both low-speed
and high-speed machines are running satisfactorily when
equipped with either siphons or dippers. In any comparison of the
two, it should be kept in mind that the essentials of any good
drying system are to keep the dryers free of air and of condensate,
and to prevent the escape from the machine of uncondensed
steam. The dippers fill the last two requirements perfectly,

because they will pick up water and discharge it from the dryers to a trap; but some other means must be provided for getting the air out of the dryers. In many cases, air cocks are placed on the face of the dryers or are tapped into the ends of the journals, which are drilled for this purpose. Siphons, on the other hand, require a steady, continuous pressure drop between the inside of the dryer and the water header in order to lift the condensate from the dryer; therefore, a more complicated arrangement is needed to prevent the loss of uncondensed steam, as, for example, special, individual air-vented traps or a circulating system, both of which arrangements are described later. The siphon is the ideal method of removing air from the dryer.

The modern open-trough, double dipper is probably as satisfactory as any design of dipper for removing water. But, since a dipper is a revolving part of the machine, it must be balanced; also, great care must be taken that neither a dipper nor a siphon become loose, and thus be a noisy, useless nuisance, rattling around inside the dryer.

It should be noted that there is a critical speed of dryer, at which the water is kept thrown against the inside of the dryer shell by centrifugal force, lying in a comparatively uniform layer over the whole inside of the cylindrical surface.

Dippers will operate successfully in 48-inch dryers up to a paper speed of 600 feet per minute, and siphons to nearly this speed. For higher speeds of paper, dryers of larger diameter should be used.

244. The Steam Joint.—The rubbing surfaces of the moving and stationary parts of the steam joint are shaped like a ball fitting into a socket. The ball is ground into the socket until only a slight pressure on the ball will make the joint both water tight and steam tight. The shape of this joint, see Fig. 70, allows the part of the joint that is bolted to the hollow journal of the dryer to turn with the dryer, and its ball-like end fits snugly while turning in the cup-like socket of the part of the joint that is attached to the piping. These joints should be tight when the side bolts joining the two parts are only a little more than hand tight. If the joint is not steam tight when given, say, a quarter of a turn of the wrench over hand tightness, it should be taken off at the end of the week, when shutting down, and re-ground. These joints can be tightened so hard as to stop the paper-machine engine.

If the surfaces of the ball-and-socket joint are scored by grit or other foreign matter, the joint must evidently be re-ground before it can again give good service. When first installed, steam joints are sometimes equipped with springs, which are so proportioned as to take care of a maximum of, say, 20 pounds per square inch; but new springs must be furnished that are suitable for higher pressures, when a higher pressure will ultimately be used on the dryers. The springs should never come coil on coil, as such a condition, when cold, would induce a very powerful drag or brake on the dryer when the spring became heated.

245. Lubricating the Joint.—The lubricant best suited to a steam joint should have sufficient body to keep the rubbing surfaces free from contact with each other under the maximum pressure; but it should possess the greatest fluidity possible under these conditions. It should also have a high temperature of decomposition, and should be free from all tendency to corrode the surface of the metal. The writer has found a good grade of cylinder oil to be most satisfactory.

Never put waste in the oil pans, because it is then impossible to tell whether the oil hole is open and the joint being lubricated or whether the waste is merely being oiled. If the pressure on the moving surfaces of a steam joint is too great, *i.e.*, if the joint is too tight, the joint acts as a brake of considerable power; and if the machine tender allows the steam joints to be tightened every time they leak, instead of re-packing or repairing them, he is not only wearing out the joints but he is also putting an unnecessary load on the driving-shaft belts and the engine, thus wearing out equipment and wasting power.

OPERATION AND MANAGEMENT OF DRYERS

CONTROLLING THE STEAM SUPPLY

246. Conditions for Efficient Operation of Dryer Part.—The dryer part depends on three principal factors for its efficient operation: first, on the arrangement of the piping that supplies steam and removes condensation from each dryer; second, and this is almost as important, on the proper control of the felt tension; third, on the proper supply of dry air in the right place to

carry away the water. Probably most of the moisture (water) leaves the paper between the dryers, not while covered with the felt. The slight pressure of the moist air next the paper when so covered is relieved on contact with the air, and opportunity is given for the evaporating moisture to be absorbed.

247. Necessity for Having Free Circulation of Steam.—The main object to be aimed at in piping up the dryers is to keep up a free circulation of the steam. Steam is a non-conductor of heat; and since a stationary body of steam transmits heat slowly, by convection, the outside of such a body of steam may lose a large part of its heat, while the inside remains at nearly its original temperature. To maintain a constant supply of heat, which will give a uniform temperature across the face of the dryer and thus insure uniform drying across the sheet of paper, it is necessary to keep the steam on the move inside the dryer shell. To accomplish this, there must be a difference in pressure, which should be about half a pound per square inch between the steam header and the dryer and another half pound between the dryer and the water or drain header.

248. A Steam-Pressure Controlling System.—One method of obtaining approximately these conditions and forcing circulation
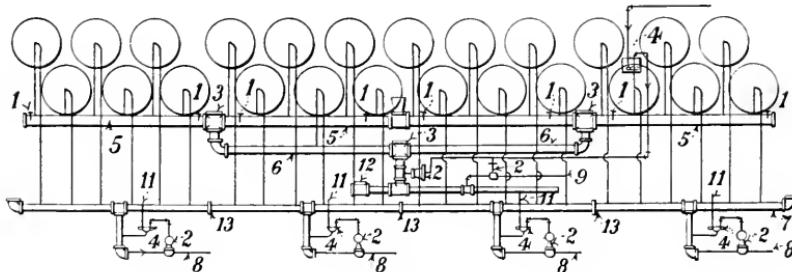
FIG. 71.

of steam is indicated in Fig. 71. The steam header, or supply pipe, is shown divided into two sections by distributing valve 3, both sections being again divided by two other distributing valves 3, so the proportion of steam to each section can be controlled. The exhaust steam from the engine passes through the diaphragm-operated valves 2, which are automatically controlled, so that the total quantity of steam to the dryer nest is varied in accordance with the pressure in the dryers. If, in drying the paper, more steam than usual is condensed, thus

causing the pressure in the dryers to drop, this causes the diaphragm to open valve 2 and let more steam into the system. If the steam pressure in the dryers gets too high, this diaphragm, which is controlled by air pressure, shuts valve 2, and the steam pressure is brought back to normal. The steam that is admitted through valve 2 is distributed to the two ends of the dryer part, in the proportion desired, by valves 3, which are adjusted by the operator.

The water header is divided into four parts, the three flanges 13 being blanks; this is done to keep the pressure in the water-header sections from getting so high as to exceed the steam pressure in any dryer. With a piping arrangement of this kind, by changing the pressure in the water header, the paper maker can have more pressure in any one of the four sections of the dryer part than in any of the others; at the same time, the steam in the higher pressure part cannot escape through the water header and, by thus communicating with the others, raise the pressure in any dryer in those sections in which the paper maker wants a low pressure.

249. Other Steam-Circulating Systems.—Various means of circulating the steam in the dryer part have been patented and installed. Some cause the high-pressure steam to enter one section, pass through the dryers and the water header into a second section of dryers, and so on, if desired, into a third section; this method maintains a rapid circulation of steam and gives good results. The idea is to dry the paper gradually, by having the hotter, high-pressure steam affect the hot, nearly dry paper first. Heating the paper gradually is less likely to produce blisters and cockling.

250. Special Considerations.—The paper maker must remember that special drying systems are expensive and often troublesome, if not carefully installed and operated. A few iron filings, a piece of a washer, or a piece of putty, which may happen to get into the piping or into a valve, will cause a great deal of trouble, and will be hard to find after the system is closed. It should be a rule never to alter a dryer-pipe installation when the machine is doing well; if there be something wrong, try to ascertain what it is and endeavor to devise a remedy. If the dippers and siphons are in good condition, get the air out of the dryers by means of pet cocks in the heads. Put a steam gauge on the

steam header and on the water header; then, if the water-header reading is equal to or greater than the steam-header reading, change the gauges. If the water-header reading still shows high, blank off the part that is getting the most steam, thus preventing high pressures elsewhere in the pipe.

The temperature of the dryers must be accurately controlled and maintained uniform; otherwise, some rolls of paper will be too wet and some too dry. The thinner the layer of air between the dryer and the paper the better is the drying. Excessive drying is also a source of breaks on the dryers, the paper winding around a dryer and often necessitating the stopping of the machine to get it off.

251. Automatically Controlling the Steam Supply.—Nearly every paper machine is driven by a steam engine or a steam turbine, and their exhaust steam should furnish all the heat required for drying the paper under normal conditions. But papers differing in quality and weight require different amounts of steam in drying. There are three general methods of obtaining automatic control of the steam supply; they are based on (*a*) condition of the paper, (*b*) pressure in the dryer, and (*c*) temperature in the dryer.

By method (*a*), a light roll, on free arms, rides on the paper as it passes from one dryer to the next; it is situated near the middle of the dryer part, and one of the arms is connected to an apparatus for operating a steam valve, so as to admit more or less live steam to the dryers. If the paper is too damp, it slackens, the roll falls, and the steam valve opens; but if the sheet is too dry, this operation is reversed. When once adjusted to the speed and weight of the paper, this device works well.

Methods (*b*) and (*c*) are similar in principle, the reason for classifying them separately being that a pressure gauge does not take account of the small amount of superheat that the steam sometimes possesses. The steam in the dryer is generally in a saturated condition, in which case, the pressure gauge gives an accurate measure of the temperature as well as of the pressure. In either case, the result is, practically speaking, *thermostatic control*, and the dryer temperature is maintained constant when the apparatus is set for particular paper conditions.

252. Steam Traps.—Steam is one of the most valuable commodities used in the mill; and, next to water, it is the most easily

wasted. A large amount of steam is required for drying paper, and the profits of the mill may depend on how efficiently it is used. To prevent steam from blowing through the siphon or dipper and still permit the escape of the condensation, steam traps are used. There may be one trap to each dryer; more frequently, however, there is one trap for several dryers, or even a single trap for all the dryers.

The purpose of the steam trap is to hold the steam in the dryers until it has condensed and given up all its latent heat. In changing from a pressure of, say, 10 pounds per square inch, gauge, to 0 pound per square inch, gauge (atmospheric pressure), a pound of steam gives up only 9.8 B.t.u.; but when the steam at atmospheric pressure condenses to water of the same temperature and pressure, it gives up 970.4 B.t.u., or nearly 100 times as much. Steam at 10 pounds pressure is, of course, hotter, *i.e.*, has a higher temperature, than at atmospheric pressure; consequently, in some systems, the hot steam is carried as steam through a section of the dryer part, to be condensed in another section, that next the presses. This permits the passage of more heat at a lower temperature, which is the best way to dry paper.

254. Types of Steam Traps.—There are two general types of steam traps—the **bell type** and the **tilting type.** The former consists essentially of a chamber, in which hangs a bell that is constrained to move vertically. The steam and the condensate enter under the bell. Steam escapes under the bell, which rises as the water gathers, until, at a certain point, a water discharge is opened and the steam-exhaust supply is temporarily closed. The water is forced out, and the bell falls until it operates to close the water discharge opening, the steam outlet being again opened. An air vent over the bell lets out the non-condensible gases. The hot water goes back to the boiler, and the separated steam is generally sent to one or more dryers at the wet end, usually through a common header, which connects all the traps.

The second (tilting) type of steam trap is essentially a two-pocket cylinder, mounted at the middle of the long axis. Steam and water enter at one end, the steam passing baffles and escaping; the water accumulates until that end is heavier than the other, when it falls. This movement shuts off the steam inlet and outlet, and it opens the water outlet; at the same time, the water outlet from the other end is closed, while the steam inlet from the dryers and the outlet from the trap are opened. In

some traps, a tilting bucket is enclosed in the vapor chamber; it is operated by the weight of water condensed in the bucket.

In some systems, a vacuum pump removes water and air from the traps. The pressure in the trap is, of course, always lower than in the dryer.

When it is decided to use valves on each dryer, on both the steam supply and the water discharge, and a trap is used on each dryer, then the valve on the water discharge is closed only when it is necessary to repair the trap. The valve on the steam supply will control the quantity of steam to the dryer. Under these circumstances, a good siphon performs uniformly as long as the steam pressure is uniform and the paper machine is running uniformly.

Traps are always liable to get out of order; and if there are too many, some are always out of commission. It pays to use good traps.

255. Air Pumps.—Methods involving forced steam circulation by means of air pumps are unexcelled, when they receive constant attention. But the human factor in the problem is a large one, and few paper mills can thus afford to complicate their paper-making facilities.

256. Control at the Press End of Dryer Part.—The steam supply to the press end of the dryer part should be capable of easy control by the paper maker. A valve on each of the first few dryers will enable him to cut the supply, if the surfaces of the dryers become hot enough to spoil the paper; and such a condition will soon be manifested by the surfaces of the dryers becoming covered with fluff or filler.

The paper at the calender end should still contain 8% or 9% of moisture, because paper that is over-dried is spoiled. In all finer grades of paper, the use of a smoothing press before the first dryer, when the paper still contains at least 60% of water, will compress the fiber into the surface and, at the same time, compact the body of the paper, so that a better finish can be obtained.

HANDLING DRYER FELTS

257. Importance of Controlling Felt Tension.—The control of the tension of the felts is a most important feature of the management of dryers. Efficient and uniform drying action

of the dryer surfaces can be obtained only by securing a close and uniform contact between the paper and the dryers. A careful inspection of the felt tension throughout the nest will often indicate adverse conditions, either because the felt tightener is badly placed or because it does not have sufficient range and promptness of action as a felt loosener. A dryer felt, if made of cotton, will shrink violently when it is locally wet, and it will slacken promptly as it dries. If the tighteners, or as they may truly be called, loosening devices, are not so placed as to nullify the evil effects of this shortening and lengthening of the felt, the life of the felt and the quantity and quality of the output will suffer.

258. Putting on a New Felt.—The proper method for putting on a new felt will now be described. First, slack up on the tighteners, and then cut the old felt right across the machine. If there is no old felt on the machine, a length of good stout twine, of hemp or sisal, must be threaded through the dryers, in the middle, following exactly the path of the felt around the dryers, felt rolls, tighteners, etc. The new felt, which comes in a roll, is then laid down across the machine, between the last dryer and the calenders, or the size press, if there be one. The end is cut square; if necessary, ravellings from the cut part are used for sewing the ends together later on. The end of the new felt is then sewed to the end of the old felt; or, if there is no old felt, the end of the new felt is attached to the end of the threaded twine. The dryers are then started up. If the lower felt is being replaced, the new felt goes down under the dryers; the other loose end of the old felt is taken, as it comes out, and is passed over the top of the calenders, to be wrapped around a reel drum and wound up. When the last of the old felt comes out, the end of the new felt is detached from it, and is sewed tightly to the other end of the new felt. The two ends of the felt are placed together, the edges pointed in, and the seam is sewed about 1 inch in.

The seam is conveniently made by tacking the loose ends, joined squarely, to a board, with about $1\frac{1}{2}$ to 2 inches extending. Following a thread, a straight line is drawn across the felt. A long ravelling, as long as can be handled without snarling, is threaded into a sailmaker's needle, and the two ends are sewed together on the mark. A good stitch is to put the needle down about $\frac{1}{4}$ inch from the edge, up about 2 inches along the line, down again through the first hole, up through a new hole 4 inches from

the first, down again through the second hole, and so on. A quicker method is to pass up and down alternately, every 2 inches or so. For a nice job, the ends should be inside the felt, so as not to mark the paper; but they are often left outside, since it is then much easier to sew.

A top felt is replaced in the same manner as that just described, except that the old felt cannot then be passed so conveniently over the calenders and wound on a reel drum. In this case, the old felt is either rolled on a core by hand, or it is wound up on the last lower dryer roll, the sweat roll, or in any way that is convenient; frequently, a roll is started on a core, and then wound by resting it on, or between, dryers.

259. Strength of Felts.—Dryer felts, unlike press felts, are usually made of cotton instead of wool, and are sometimes $\frac{1}{4}$ inch thick. They are much stronger than press felts, having a breaking strength of 300 pounds per inch of width; the breaking strength of the average press felt is about 60 to 70 pounds per inch of width, though a fine-writing, third-press felt of a tissue machine may have a breaking strength sometimes of 125 pounds per inch of width.

260. Starting the Felts.—The great strength of a cotton dryer felt, in conjunction with its decided shrinkage when wet, cause tremendous strains on the dryer felts and rolls. In starting up a dryer part with a new felt or, for that matter, with an old felt, start the dryers free of paper; run slowly, with the felt stretchers slack at first, watching the tighteners and guides, to see that all the rolls turn and that the felt does not catch anywhere.

Turn steam into the dryers for about 20 minutes before starting up and look to see that the dryers are empty of water. If a dryer be practically half full of cold water, it will act as a sweat roll, and the dryer edge next the back side will get wet from the vapors there; this will not only spoil the paper but may also result in the loss of a dryer felt. When run cold, dryers are likely to rust and mark fine papers.

261. When putting on a dryer felt, it may tend to run to the front side or back side of the machine, notwithstanding that every precaution has been taken to keep the run of felt straight and to sew the seam square across. In correcting this, the machine tender should bear in mind the simple rule: *A dryer felt will run to the tight side when tightened at the side at which it leaves the dryer*

cylinder; and it will run to the slack side when tightened on the side that is going to the cylinder.

The seam should always be squared up on starting, and any tendency to run ahead on either side can be corrected by making the travel of that side longer; if this be not done, the felt will be unevenly stretched, and it will give plenty of trouble before it has been in service very long.

When shrinking, a dryer felt can exert a pull of 30 pounds or more per inch of face of felt rolls, unless the stretch roll automatically compensates for the shrinkage. This puts a bending moment on a felt roll, which will cause it to sag in the middle until the felt becomes too loose at the middle and too tight at the edges. The result is that the paper is not held tightly against the dryers and remains wet in the middle; and when the local felt-tension conditions change, a break is almost inevitable. In any case, a good roll at the winder is practically impossible. Cockling troubles also result from these conditions, because minute bubbles of steam make small blisters in the paper, and lack of pressure imparts a sort of puckering to the paper as it dries.

262. Flapping.—Often when following the course of the paper through the dryer nest, the observer will perceive a continuous flapping of the dryer felts at certain points. This **flapping** is almost invariably caused by inaccurate spacing of the dryer gears, or in some imperfection of the drive. Many old machines have been speeded up in order to increase production, and the result aimed at has been lost because of continual breaks of paper in the dryer nest, due to the use of the old-fashioned cast gears. The remedy is always to order cut gears when the paper speed is over 250 feet per minute. By watching a flapping felt and counting the flaps per revolution of a dryer, the relationship between the drive and the flap will be perceived.

Flapping of dryer felts may also be caused by an eccentric dryer, one that does not rotate about its axis; it may likewise be caused by a warped dryer. To ascertain whether or not a dryer is eccentric or is warped, hold a stationary pointer close to the revolving dryer surface; if the revolving surface is always the same distance from the pointer, the dryer is turning true, but if not, it is eccentric or warped, and the degree of eccentricity can be readily noted.

A lack of symmetry of a drying cylinder, due either to eccentricity of its bearings or to its not being a true cylinder, will

produce a circumferentially imperfect movement about the axis of revolution, which causes a flapping movement of the paper as it journeys from one dryer to another; and this occurs if either or both of two successive dryers are imperfect. Flapping is sometimes due to a lack of proper balance between the speed of the paper, the diameter of the dryers, and the relative position of the dryers.

263. Cause of Breaks.—It is well to note here that a dryer that is not properly machined, so that the foundry skin is removed, is liable, if not well "seasoned" before being machined, to become misshapen when subjected to the strains caused by the changes of temperature that are a part of the operation of paper drying. Many a break may be caused by the stress of the paper resulting from a misshapen dryer or an eccentric dryer movement. The distortion of the dryer movement may be inherent in the dryer itself, or it may be due to unevenly worn bearings or to imperfect gears. Broke may be the result, however slight the non-uniformity of the dryer travel. The reason that the paper does not break oftener when flapping occurs is because of the natural elasticity of a fabric composed of cellulose fibers.

The driving side of a nest of dryers will sometimes exhibit this phenomenon when it is not evident on the tending side, because the bearings on the driving side are not as easily lubricated; they may, for that reason, wear more rapidly, thus producing a relatively imperfect mechanical movement.

264. It requires time to evaporate the water in the paper and change it into steam on the dryer, and time to remove the vapor from the paper as it travels from dryer to dryer. Paper shrinks as it dries, and it stretches as it becomes damp, and if the air it meets is moisture laden, the paper becomes cooled and dampened between dryers, if the length of lead is too great for the speed of the paper; such a condition is another cause for flapping.

265. The Spear and Its Use.—When paper breaks and winds around a dryer, it must be cut off with a spear. The **spear** is a long, light pole, with a sharp steel head that is sometimes slightly curved. It is jabbed under the edge of the paper, as low as possible on the up-coming side of the dryer, and is pushed as far as possible; but it is withdrawn when the cut is at the highest point, as the dryer turns. A new jab is made as the cut again comes up, until the paper is cut clear across. It is a good plan

to run the cut part over to the next dryer and along the lower tier. On a fast machine, the paper is immediately broken at the press or wire, and the dryers are slowed down or stopped; this is quicker in the end, and is less dangerous. It is not safe to stay near the man who is using the spear.

EVAPORATIVE EFFECTS

266. Conditions for Maximum Drying Effects.—In a dryer nest, the diameter of the dryers being as large as possible, the maximum drying or evaporating effect per dryer should be imparted to (*i.e.*, as much water should be evaporated from) the paper as can be taken care of by the air that meets the paper between the dryers.

Between certain limits, it is evident that it is possible to obtain the same actual and relative amounts of dryer contact and air contact for the paper as it travels on its way through the dryers, whatever be the diameter of the dryers, whether 48 inches or 60 inches; these limits are determined by the width of the machine, because the diameter of the felt rolls must increase with the width, which influences the spacing of the dryers.

267. It is important that the dryer nest be so designed that the paper will come in contact with a dryer before the felt binds it to the dryer; and it is important that the felt should leave the paper before the paper is constrained to leave the dryer.

In considering the relative position of dryers and the distance between the paper and dryer contacts, it must be remembered that the gears are all of the same diameter, and that the alternate upper and lower gears are in mesh; there must be clearance between gears on contiguous lower dryers and contiguous upper dryers, and this rule can be altered only by the use of idler gears.

268. To recapitulate: in order to obtain the maximum output from a given nest of dryers under normal working conditions, the following practical conditions must be met.

(*a*) The dryers must be perfect cylinders, revolving on true mechanical journals, whose axes should coincide with the theoretical axes; the gears must be accurately cut and accurately connected with the dryers.

(*b*) The length of contact of the paper with each dryer and with the air between the dryers must be adjusted to prevent flapping.

(c) The paper must meet each dryer before the felt, and must leave the dryer after the felt, every time.

269. Ventilation.—Good results cannot be obtained from the dryer nest unless the ventilation conditions are such that an ample supply of moderately dry air is constantly rising around the dryer nest. From 2 to 3 tons of water must be carried away by the air for each ton of paper made; and if the air supply is not ample, good drying conditions are not possible. A homely comparison that may serve to impress the idea on the reader's mind is: a washerwoman prefers a windy day to dry the clothes, even when the sun is not shining, to a sunshiny day when there is no air stirring; but the best day is when there is a warm, dry breeze.

270. Amount of Water Evaporated by Dryers.—The amount of water that the dryers evaporate per day is easily found when certain quantities are known or specified. Thus, let

N = total weight of paper delivered by the dryers per day of 24 hours;

n = average per cent of water in N (expressed decimally);

M = weight of bone-dry material in the paper delivered;

m = weight of water in N ($= n \times N$);

e = weight of water evaporated by dryer nest;

w = weight of water in paper entering dryers;

W = total weight of paper and water entering dryers;

p = per cent of bone-dry material in W (expressed decimally).

All weights, must be expressed in the same unit, say the ton of 2000 pounds.

Then,

$$W = M + w = M + m + e = M + nN + e; \qquad (1)$$

from which, $$M = W - W = W - m - e. \qquad (2)$$

Further, $$M = pW; \qquad (3)$$

$$W = \frac{M}{p}; \qquad (4)$$

and $$M = N(1 - n). \qquad (5)$$

Also, $$N = M + m; \qquad (6)$$

$$N = \frac{M}{1 - n}; \qquad (7)$$

$$W = \frac{M}{p} = \frac{N(1 - n)}{p}; \qquad (8)$$

and $$e = W - N. \qquad (9)$$

These formulas are very simple, and they are all self evident. The following example will show the application of several of them. The per cent of water in the finished paper (denoted above by n) varies considerably; it usually amounts to 6% to 9%, though 10% is considered as commercially dry paper. The per cent of dry material entering the dryer part (denoted above by p) is determined by actual test in each case.

EXAMPLE.—A machine has a total output of 25 tons of paper per day of 24 hours, and the paper contains 10% of water. It is found by test that 38% of the mixture entering the dryers is bone-dry material. (a) What is the total weight of paper and water entering the dryers per day? (b) What is the total weight of water evaporated per day by the dryers?

SOLUTION.—(a) Here $N = 25$ tons, $n = .10$, $p = .38$, and it is desired to find W, the total weight of water and paper entering the dryers. The given quantities are N, n, and p, and W is to be found. These quantities, and only these are contained in formula (8); hence, using this formula,

$$W = \frac{N(1-n)}{p} = \frac{25(1-.10)}{.38} = 60 \text{ tons, very nearly.   Ans.}$$

(b) By formula (9),

$$e = W - N = 60 - 25 = 35 \text{ tons.   Ans.}$$

271. Number of Dryers Required.—A rough approximation to the capacity of the dryer part may be arrived at as follows: If the paper being made is newsprint or its equivalent in furnish and weight, allow one 48-inch dryer for every 20 feet per minute of paper speed; or, for a 60-inch dryer, allow one dryer for every 25 feet per minute of paper speed. Thus, if the paper speed be 600 feet per minute, there should be $600 \div 20 = 30$ 48-inch dryers or $600 \div 25 = 24$ 60-inch dryers. For book and writing papers, allow one 48-inch dryer for every 10 feet. per minute of paper speed.

The following table represents actual practice; it checks quite closely the rough rule just given:

BOOK AND WRITING PAPERS

Maximum speed of paper, feet per minute	No. of dryers. Diam. (inches)		
	48	60	72
250	24	20	17
325	30	26	22
400	36	32	27
450	42	36	30
500	48	40	37
Newspaper			
300	15	12	10
375	18	15	13
450	22	18	15
525	26	21	18
600	30	24	20
1100	. .	. .	40

272. Calculating Dryer Surface Required.—The following empirical formula may be used for calculating the amount of dryer surface required for various kinds of papers. In this formula,

S = speed of paper in feet per minute;

L = peripheral length (in feet) of dryers in contact with paper when in operation;

t = temperature of steam at pressure carried in degrees Fah.;

d = thickness of dryer shell in inches;

w = weight of paper in 500 sheets, 24″ × 36″.

Then,

$$S = \frac{2.7L(t - 212)}{wd}; \tag{1}$$

and

$$L = \frac{Swd}{2.7(t - 212)}. \tag{2}$$

EXAMPLE 1.—Suppose it is desired to make 30-pound newsprint at a rate of 600 ft. per min.; how many dryers having a thickness of ¾ in. are required when the steam pressure is 10 lb. per sq. in., gauge?

SOLUTION.—Referring to the steam table at the end of Vol. III, the temperature of the steam at 10 lb., gauge, is 239.4°. Neglecting the fraction, the value of t is 239. Substituting in formula (2) the values given,

$$L = \frac{600 \times 30 \times .75}{2.7(239 - 212)} = 185 \text{ ft.}$$

The value of L just found is the length of the periphery of dryer shell that is in contact with the paper. But, since a little less than one-half of the periphery of any dryer is in contact with the paper (see Art. **226**), the periphery of a single dryer must be greater than $185 \times 2 = 370$ ft., which is far too great for any dryer. The periphery of a 48-inch cylinder is $\frac{48 \times 3.1416}{12} = 12.5664$ ft., and one-half of this is 6.2832 ft. Assuming that the length of the arc of contact between the paper and the dryer is 6 ft., the number of 48-inch dryers required is $185 \div 6 = 31$. Ans.

EXAMPLE 2.—How many feet of peripheral contact on dryers is required for 18-pound tissue at 150 ft. per min., the thickness of the dryer shell being $1\frac{1}{2}$ in., and the steam pressure 75 lb. per sq. in., gauge? How many 60-inch dryers would be required?

SOLUTION.—Referring to the steam table at the end of Vol. III, the temperature of the steam is 321° very nearly. Substituting in formula (2) the values given, the total length of the peripheral contact is

$$L = \frac{150 \times 18 \times 1.5}{2.7(321 - 212)} = 13.76 \text{ ft.} \quad \text{Ans.}$$

In example 1, it was found that the arc of contact for a 48-inch dryer might be taken as 6 ft.; for a 60-inch dryer, it may therefore be taken as $6 \times \frac{60}{48} = 7.5$ ft. Consequently, the number of 60-inch dryers is $13.76 \div 7.5 = 1.83+$, or 2 dryers. Ans.

273. Calculating the Air Supply.—The water that is evaporated by the dryers is carried away by air, which is supplied and taken away by some mechanical means. A given quantity of air, say a cubic foot, will absorb a certain amount of moisture (water); and if the air be dry and warm, it will absorb much more moisture than cold, damp air. Under the usual working conditions, it takes about 40 pounds, which is equivalent to about 500 cubic feet, to carry away 1 pound of water. Referring to the example of Art. **270**, the weight of water evaporated by the dryers in 24 hours was found to be 35 tons, which is equivalent to $\frac{35 \times 2000}{24 \times 60}$ = 48.6, say 50 pounds of water per minute. Consequently, to dispose of this water, air must be supplied to the dryers and conducted away from them at the rate of about $50 \times 500 = 25,000$ cubic feet per minute; and this is the amount necessary to furnish when making 25 tons of paper per day under the conditions specified.

274. Supplying the Air.—The air may be supplied by a fan that is situated in the basement. The fan blows the air through an air duct, which has upright outlets at intervals, and which discharges the air into the dryer nest. This method is direct and efficient; and if the system be well designed, it will increase the output of the machine in both quantity and quality.

Placing steam pipes either below the dryer nest or above it, will induce a strong current of up-going air; but by placing the steam pipes below the dryer, the air is warm when it reaches the dryers, and warm air will absorb more water than cold air. If the steam pipes are placed above the dryer, they will induce a current of colder air through the nest than if they were placed below the dryers; but when in this latter position, they have the advantage of keeping the air from getting chilled by cold drafts from the windows or the cupola in the room, or by conduction through a poorly insulated roof, which will force the air, if chilled to the dew-point, to drop its water on the top felts in the form of dew or light rain.

The air leaving the dryers carries with it, in the form of water vapor and sensible heat, the equivalent of most of the heat abstracted from the steam in the dryers. A recently patented system recovers much of this heat by warming the incoming air.

275. Humidity.—There are three principal factors concerned in the removal of the water evaporated by the dryers: (a) the volume of air passing through the dryer part relative to the amount of water to be evaporated; (b) the temperature of the air; (c) the humidity of the air. A cubic foot of dry air at any particular temperature will hold a certain definite amount of water, the exact amount depending on the temperature of the air. When the air has taken up all the water it can hold, it is said to be **saturated**. If saturated air be cooled, it will deposit some of its moisture in the form of dew or rain; but if it be heated, it can then absorb more moisture. Saturated air is also said to have a **humidity** of 100%; and air containing less moisture than that required to saturate it, will have a humidity ranging from 0%, when it is perfectly dry and moisture free, to 100%, when it is saturated. The less saturated it is the more moisture it can absorb, and the more it can be cooled before reaching the **dew point,** which is the temperature at which precipitation or condensation occurs, i.e., the temperature at which the humidity is 100%. The student is advised to re-read Arts. **129** and **130** of

Elements of Physics, Part 2, in Vol. I, and to refer to the use of the **hygrometric chart** in Vol. V, under *Paper Testing*.

276. Removing the Air.—Referring back to Fig. 65, the illustration shows a design of a hood *H* over a dryer nest, with one or more stack openings *V* on top. Each stack is provided at its outlet with a fan for drawing the moisture-laden air from the dryer nest and discharging it out of doors. In some mills, a tall stack, with natural draft, is preferred to the fan. Since the arrangement of dryer hood, fans, and stacks here shown will tend to draw the air from the machine room more easily than from the inside of the dryer nest and from under the dryer felts, and since the air from the back, or driving, side is generally more moisture laden than on the front side, it is a good plan to have the hood overhang more on the driving side and to turn it toward the dryers, so as to induce the air to come from under the felt and into the hood. If moist air be not removed before it cools, the moisture is condensed out when the air strikes a cold surface, and falls like rain from a cloud. It will therefore be seen that the design and construction of the roof is of considerable importance. In some cases when fans are in use, the stacks may discharge through openings in the walls instead of through the roofs.

277. Roofs.—A high roof, with a large-size cupola, is a good aid to paper drying. The roof should be of an anti-sweat design, preferably with an air space between the roof proper and a false roof that is composed of paper, asbestos, or composite boarding, which is supported by the main-roof trusses. The cupola should be high enough to allow of ample window spacing, which should run from end to end of the cupola; and the lower sashes should be so arranged as to afford an easy way out for the moisture-laden air of the machine room, but still keeping the rain from beating down in case of a storm.

The accumulation of moist air under a wooden roof induces decay; untreated timbers seldom remain in good condition for more than seven years. The proper construction of roofs has received considerable attention and study in recent years. The reader is referred to articles on this subject by R. J. Blair, in *Pulp and Paper Magazine of Canada* for Jan. 1 and 8, 1920; in *Paper*, Vol. 25, pp. 819–827 (1919); and by H. S. Taylor, in *Pulp and Paper Magazine of Canada* for July 8, 1920.

278. The Size Press.—An important part of many paper machines that make writing papers is the size press.   As the paper comes from the last dryer, it is usually cut into strips by a set of slitters, similar in design to those described in Art. **303,** Part 4 of this section, and which are mounted on the end of the dryer frame.   The strips, cut in accordance with the size of the sheets desired, are passed under a paper roll to submerge the paper in the size solution, then under and back through the nip between the lower and upper size-press rolls; they are then led to a cutter and layboy (see *Tub Sizing and Finishing,* Vol. V), if loft dried, or over a short dryer nest, of 5 or 6 dryers, if sized in full width. Machines are now equipped with slat or festoon dryers, to produce an accelerated air drying; these machines are described in Section 3, Vol. V.

In the case of thin papers, it is customary to wind the sized paper on reels and cut it later for loft drying; it may even be sized in an operation that is subsequent to the making of it.

PAPER-MAKING MACHINES

(PART 3)

EXAMINATION QUESTIONS

(1) (a) What is meant by the dryer section? (b) What portion of the removal of water from the paper takes place here?

(2) (a) Explain the function of the smoothing rolls? (b) Where are they located and why?

(3) Why is a felt used on the dryers, and of what is it made?

(4) Does a dryer felt stretch or shrink when wet?

(5) Explain the contrivance by which any change in the length of a felt is taken care of automatically.

(6) Why should air and why should water be removed from dryers?

(7) Describe two methods for removing water?

(8) Explain the presence of water in the dryer.

(9) Suppose 1 lb. steam is put into one dryer at 10 lb. gauge pressure and removed as steam at 0 lb. gage, and 1 lb. into a second dryer at 0 lb. and removed as water at the same temperature; which will dry more paper?

(10) What is the principle of the guiding of felts?

(11) (a) What is the function of the steam joint? (b) What precautions should be taken with it?

(12) What means may be used to maintain a uniform temperature in the dryers?

(13) What is a steam trap for, and how does it work?

(14) Explain how a new dryer felt is put on.

(15) Mention some causes of flapping of the paper on the machine.

(16) What factors influence the rate of drying of paper?

(17) If a machine were to make 55 tons of paper containing 8% moisture in 24 hours and the paper contained 30% bone-dry paper on entering the dryers, how much water would be removed in drying?

(18) What is meant by (a) dew-point? (b) humidity? (c) siphon? (d) felt dryer? (e) dancing roll?

<heading>SECTION 6</heading>
PAPER-MAKING MACHINES

(PART 4)

CALENDERS, SLITTERS AND WINDERS

THE CALENDER END

DESCRIPTION OF CALENDERS

279. The Spring Roll.—At the calender end of the dryer part, the paper passes under a spring roll N, Fig. 64, before entering the nip of the calender. This is a paper roll, which is supported in spring bearings, one of which is shown in detail in Fig. 72.

Referring to Fig. 72, the bearing proper B is a floating or moving bearing, entirely supported by springs, one of which S is shown in detail; it is kept in position and adjustment by the bolt J. When the paper tension varies, as the paper is pulled from the dryers by the calenders, this spring roll (under which the paper passes) can rise or fall in its bearing because of the action of the springs; and this compensates for temporary variations of the tension.

Fig. 72.

§6   179
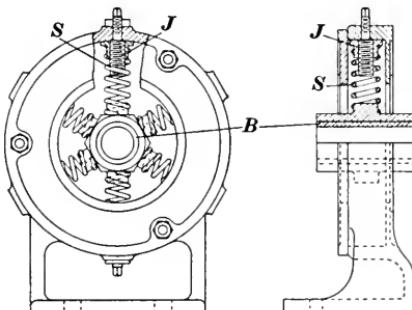
280. The Calender Stack.—Fig. 73 shows a 9-roll stack of calenders, and a similar roll is shown in Fig. 74.   The paper, as it is passed from the dryers, is brought over the top roll and enters
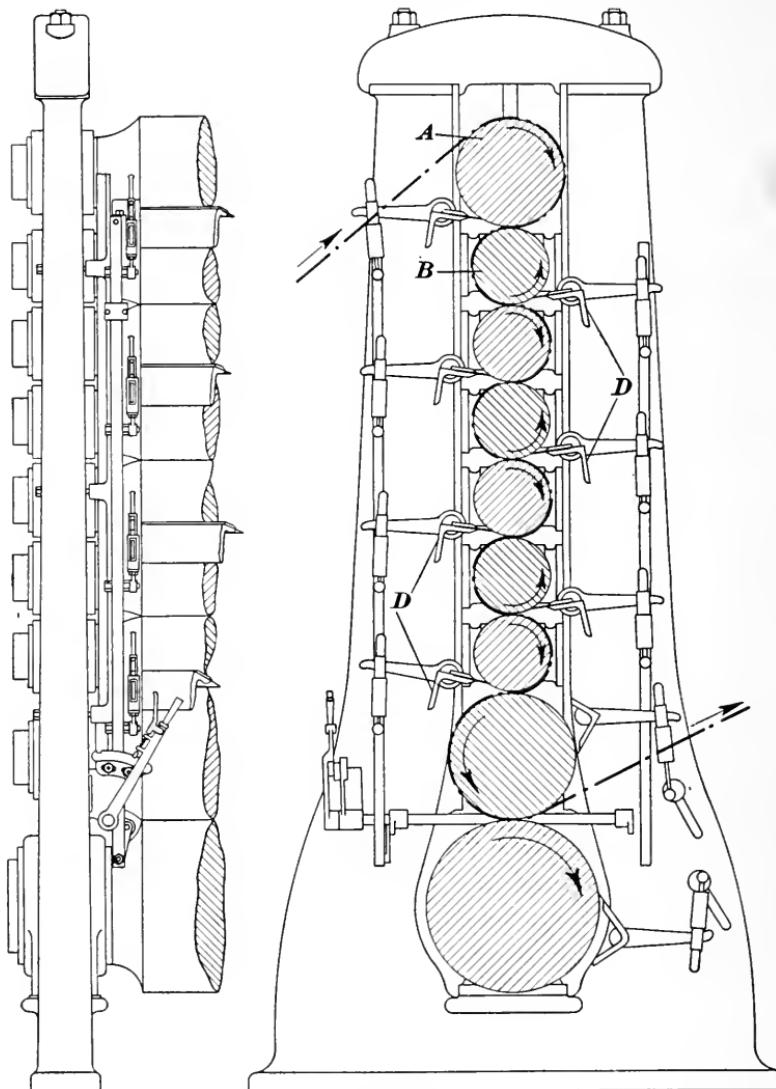
FIG. 73.

between the top roll *A*, Fig. 73, and the roll *B*, next below it. The paper is guided by bent steel fingers, or ductors, into each succeeding nip.   On coming out from the first nip, the paper is

guided back into the next lower nip, proceeding in this way from nip to nip until it finally comes out on top of the bottom roll, on the side away from the dryers and toward the reel.   In the stack here shown, the top roll turns away from the dryers, and the paper is carried over and fed from behind; consequently, if there were an even number of rolls (say 8 or 10), the paper would not pass.   With an odd number of rolls, an extra roll, called a *pinch roll*, over the top roll, is sometimes placed at the top of the stack, to help in bringing the paper over; or the paper may be passed directly to the first nip.

The steel doctor blades *D* scrape off the paper as it comes from each nip, and thus keep it from traveling up the rolls.   The ductors are on the in-running side of the upper roll of each pair of rolls; and there are usually 5 or 6 ductors on the tending side of the machine, to handle the "tail."   The doctors are always on the out-running side of the roll.   The ductors lead the paper to the nips; the doctors lead the paper away from the rolls.   (See Part 3, Art. **223.**)

A popular type of calender doctor has a universal control, by means of which, all the doctors are connected together, and all are thrown against or away from the rolls; but individual doctors can be operated independently, if necessary.   Each doctor has a flexible blade of soft metal, so the chilled-iron calender rolls will not be injured by contact with it; and the doctors are all held against the rolls with a uniform, relatively light, pressure by springs, the tension of which (and the corresponding pressure of the doctors) is adjustable.   All the doctors are operated from the front side of the machine.

The back tender throws the end of the paper into the entering nip, and it automatically feeds through the calenders until it is scraped off the reel side of the bottom roll; it is then carried by the back tender and wrapped around a reel cylinder.   On machines that are not equipped with doctors and ductors, the calender stack is a prolific source of accidents, because of the tendency to use the fingers to feed the paper through the nips.   The safe way is to draw the loose end down tight with one hand, and then push the sheet into the nip with the closed fist of the other hand. A good machine man is **Always Careful Everywhere.**

281. Purpose of the Calenders.—The purpose of the calender stack is to compact the paper and give it a fine, smooth finish; this effect is achieved on both sides of the paper by the friction

and pressure of the rolls between which the paper passes. The lowest roll of the stack is driven mechanically, and this, in turn, drives those above it by friction. There is a certain amount of slip between these rolls, and the result is that an enormous aggregate of friction acts on the paper as it passes through.

In order to give a fine finish, the calender rolls are made of a fine-grained cast iron that is susceptible of a high polish; it is important that these rolls be made of chilled iron. Since a soft paper is more easily smoothed than a hard paper, the surface of the paper is sometimes dampened (as for water finish) with a fine water spray or a steam jet, which is played on its surface as the paper enters the nip of the calenders. If the paper is made too wet, the friction of the calenders may develop black spots on the sheets; also, softening the paper at this point may reduce the size fastness of the paper.

282. Use of Sweat Roll and Smoothing Roll.—Sometimes the paper is moistened on the surfaces by passing over a **sweat roll.** This is a small roll, like a dryer, but filled with cold water to condense moisture from the air on the paper, which will soften the paper and assist the work of the calenders. Moistening the paper with the intention of obtaining a fine glaze finish is a procedure also carried on in the finishing room on the supercalenders.

The use of smoothing rolls before the dryer nest, as shown in Fig. 64, smooths the surface of the paper while it is still very moist, and is therefore soft and pliable; they squeeze down the surface to a finish with much less pressure than the calenders must exert to get the same result, and should leave more strength in the paper, with no ill effect on the sizing.

283. Moisture in Paper at Calenders.—The paper should go to the calenders containing close to 10% of water; if it contain much less, it has a dry, brittle feel, is liable to break, and, being hard, does not iron out easily. When paper is coming through in this condition, the steam supply to the dryer nest must be reduced until the moisture content of the paper is normal.

284. Calender Doctors.—When selecting calender doctors, make sure that they fulfill the following conditions: first, they must be capable of quick adjustment to, and release from, the surface of the rolls; second, they must be capable of exerting a fair pressure on the rolls; third, the blades must be flexible enough

to shape themselves to conform to the surface of the roll by means of the adjusting screws.

The steel blade ductors should lead the paper easily to the nips, so as to preclude any necessity for any one of the machine crew getting his fingers in such a position as to be drawn between the rolls.

CALENDER TROUBLES

285. Hard and Soft Spots.—As the paper is passed over the reel and is reeled into rolls, any inequalities in bulk will show quickly. **Bulk** is a term that expresses the thickness of paper as compared with its weight; a paper that is thick for its weight is said to bulk well. If a paper bulks unevenly across the machine, it will (if it does not break at the calenders) wrap unevenly around the reel cylinders, making what the machine tender calls **hard** and **soft spots** in the roll. The hard places have the best bulked paper, because the thickness of the paper makes it reel tighter than the paper that has a poorer bulk and cannot, therefore, fill the same space as the reel roll grows; this causes soft-feeling, loose places in the roll. The back tender is very prone to correct the inequalities of bulking, causing soft spots in the reel, by trying to remedy the faults at the calenders. This can be done, and sometimes must be done, by altering the diameter of the calender rolls by changing their temperature. The place where the roll is hard indicates the part of the calender rolls that can thus be heated by friction or by steam. Opposite the soft places on the reel, which show that the paper is thinner there or does not bulk well, cold air is blown by air pipes from a blower onto the calender. This tends to reduce the diameter of the rolls at these points, which reduces the relative pressure at the same points, the result being that the paper is not calendered so severely where the soft spots indicate lack of bulk.

286. Correcting for Uneven Bulking.—In order to maintain the test strength of the paper, it is better to correct first for uneven bulking through the machine. The slices are the first sources of trouble; see that they are of uniform height from the wire clear across the machine. The drier the paper is as it leaves the press rolls the better it will bulk; so look to the press rolls for uniform pressure and accurate crowning, to correct bulking troubles. An even drying across the machine is essential;

look out for felts that are damp in the center and for places where steam collects. Every paper machine has its own characteristic troubles and faults, and every part of the machine should be examined thoroughly when there is trouble in bulking. Uneven bulking can always be corrected if the causes are located; the difficulty is to find them. The trouble may be in incorrect grinding of the rolls; regrinding is the cure for this.

The machine tender should keep it always in mind that two wrongs do not make a right; hence, if the paper is unevenly bulked (is not of uniform thickness on the roll) when it enters the calenders, and if the calenders are truly ground and the bottom roll is properly crowned, then the calenders is not the place to correct for uneven bulking. A machine tender must, of course, keep the paper going, and the quickest way to correct a fault is temporarily the best way; at the same time, a little careful thinking may suggest a better remedy, one that can be tried at the end of the week, when the machine is shut down.

287. Causes of Some Calender Troubles.—The following are some of the causes of trouble at the calenders: Too little crown on the press rolls will cause soft spots on the edges of the reel rolls, while too much crown will cause soft spots in the middle of the reel rolls; in either case, all the press rolls should be calipered with micrometer calipers, and the faulty roll should be re-ground when the machine is shut down. The temporary remedy in either case is to hang more weights on the press-roll levers on the side where the paper is too thick, or to reduce the weight on the side where it is too thin. This change must be effected gradually. The trouble may originate at the slices, one side of which is probably too high. If the variation in thickness is due to variation at the center, the trouble may be due to a sag at the center of the slice, or to incorrect crowning of a press roll. The last chance to change the relative thickness of the two edges of the paper is at the calenders. Here there is a compound-lever system on either side of the machine, similar to that on the press rolls. In order to get the desired results, care and thought must be used in changing the weights.

288. Causes of Breaks.—Should the paper break between the calender rolls, examine the paper between the press rolls. First see if it is too tight, especially between the couch and the first press and between the first and second presses, where the paper

is weak and easily over-strained. If the paper is not too tight between the presses, the trouble is probably caused by a dirty wire; some of the meshes may be filled up with dirt, which keeps the suction boxes from pulling at these points, and weak spots occur in the paper.

Sometimes the wire seam is raised; in such a case, make a note to correct this, but tighten up the wire temporarily by means of the stretch roll. Look at the wet felts for dried stuff or hard spots; these can sometimes be located by examining the paper for small, dark marks and spots, as it passes from the press to the dryers. If felt spots cause the breaking, the cause can also be identified by the presence of these spots at the broken edge. These spots can often be removed by the careful use of a piece of *wool card*, which is a sort of wire brush that is used for carding wool.

Breaking at the calenders can be caused by having the draws so slack that the edges crease at the nip of the press rolls; the calenders press these creases into cracks.

Breaks at the calenders are often caused by having the paper too slack between the dryers; the tight dryer felts will then crease the paper at the edges, and it will break at the calenders. It is better to keep the first dryer cylinder cooler than the others, in order to start the heating and drying of the paper gradually.

289. Determining the Accuracy of the Crowning.—The machine tender can make an approximate estimate of the accuracy of the crowning on the press rolls when the machine is idle, by looking through the nip, to see if light shows between the rolls, at the middle, at the ends, or irregularly; and from this inspection, he may form an opinion as to whether the crowning is a cause of any trouble he may be having at the calenders. If the press rolls do not look good to him, the next step is to take out the top rolls and caliper the bottom roll; should the calipering confirm the machine tender in his opinion that the crowning is wrong, the roll should be ground in accordance with the measurements it ought to have. With a stack of calenders, however, it is not feasible to estimate whether the rolls have the proper crowning by looking between the bottom roll and that next above it when the stack is *idle;* it is necessary to have the rolls turning when endeavoring to determine by this method whether there is any error in the crowning.

Referring to Fig. 73, the arrow indicates that the bottom roll is turning clockwise, while the roll next above is turning counter-clockwise. The bottom roll is driven, and it drives the rest of the stack by surface friction. This action of the surface driving tends to push the second roll to the right in a *horizontal* direction, and the reaction of the second roll to the push it tends to give the third roll (a push to the left), combined with the force to right exerted by the first roll, tends to, and does, deflect (bend) the second roll, which causes it to leave its line of contact with the lower roll, unless the lower roll has been so crowned as to prevent this. Consequently, while the rolls might have perfect contact when idle, the contact might be very bad when running. When specifying the crowning of the lower roll, the horizontal bending of the second roll must receive as much consideration as the ver-tical bending due to the weight of all the other rolls.

Any calender stack may show light only between the ends of the rolls when standing still, as though the crowning were too much, and yet show light only in the middle when running, because the crowning of the bottom roll is actually insufficient. If there is too little crown, the reel rolls are soft at the ends; if there is too much crown, the reel rolls are soft in the middle and hard at the ends.

The second calender roll, counting from the bottom, is made larger in diameter than the other intermediate rolls, to make it stiff enough to resist the deflection (bending) due to driving. The top calender roll is made larger than the intermediate rolls, so it will give sufficient pressure on the first nip to form the sur-face of the paper and force any loose fibers into the paper. The top and intermediate calender rolls are not crowned; but the general shop practice is to make certain that they are not hollow ground, by making them a trifle (say a thousandth of an inch) larger in diameter at the middle than at the ends.

290. Variation in Finish.—The surface of the paper can be varied considerably by changing the pressure of the calenders and the number of rolls used. Calender frames are fitted with a pair of long vertical screws on either end. One or more rolls can be lifted out of commission by pulling up a yoke under each journal of the lowest roll to be lifted, by turning screws whose threads pass through threaded holes in the yokes. As the screws are stationary, except for turning, the yoke acts like a nut; and as it rises, it carries the rolls with it. Other means are also used for raising calender rolls.

For extra-high finish without the use of supercalenders, some machines are equipped with more than one stack. If a rough, antique finish is desired, calenders may be omitted entirely.

When paper is first put through the stack, there may be small pieces of paper stuck to the rolls, and these will mark the paper if not removed. The remedy is to throw some water or kerosene on the stack, or to scrape the paper off with a calender scraper; the doctor blade will take off most of the pieces. If paper winds around a roll, an experienced man can cut it off, but this is dangerous; the best way is to stop the machine (stack) and cut it away.

The friction incident to calendering generates much heat; and since this might become excessive, it is customary to cool the calenders with a blast of cold air. The air is led in by a horizontal duct, which extends across the machine behind the bottom calender roll; it is distributed by a set of vertical pipes, from which elbows direct the blast against the calenders.

REELS, SLITTERS AND WINDERS

TYPES OF REELS

291. Four-Drum Revolving Reel.—From the breast roll to the calenders, the manufacture of paper is a continuous process; but after the paper leaves the calenders, it must be gotten into a form that can be readily handled. To accomplish this result, it is generally necessary to trim the edges and slit the sheet into several strips; and the first step in this process is to wind the paper on a reel. There are a number of types of reels and winders, several of which will now be described.

A four-drum revolving reel A is shown in Fig. 74. Here the paper is wound up on one reel cylinder and is reeled off the opposite cylinder at the same time; this allows the winder to keep up with the paper machine, while giving time for removing a finished roll from the winder B and starting another roll. The peripheral speed of the winder rolls must be greater than the speed of the paper through the machine; this is to provide for unavoidable delays in changing rolls, setting slitters, starting the winder, mending breaks, etc.

292. The English Reel.—A type of peripheral, or surface, drive reel, sometimes called an **English reel,** is shown in Fig. 75, the paper being wound around the core by reason of the friction between it and the revolving drum. The large drum F is driven mechanically, and it is therefore always turning. An arm H,
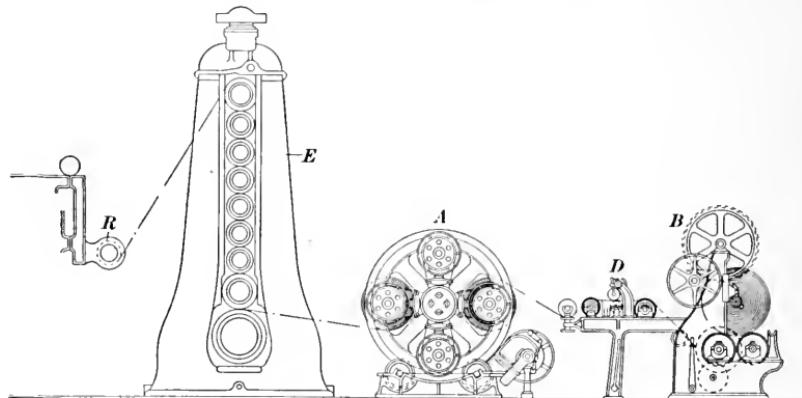
Fig. 74.

holding a core K, with the paper wrapped on it, is lowered by the wheel and gear W, so that the paper on the core rests on the large revolving drum; the result is that the paper and core are forced to revolve around the core bearings, and this winds the paper on the core. The paper roll gets larger and larger, but it cannot
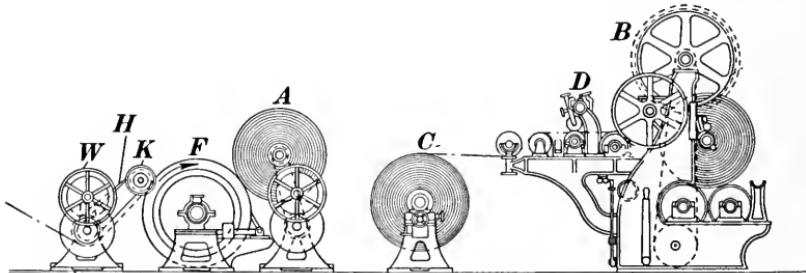
Fig. 75.

wind up faster or slower than the peripheral speed of the large revolving drum. This reel has the advantage of making reel rolls that are tight and uniform, and it therefore helps in making a good roll on the winder.

Fig. 75 also shows a reeling-off stand (see also Fig. 80), the roll of paper being taken out of the reel at A and placed in this

stand, preparatory to being run through the slitters and onto the winder. In both Figs. 74 and 75, the reel is shown at A, the winder at B, and the slitters at D.

293. Transferring the Paper.—Skill is required to transfer the paper from the calenders to the reel. On fast machines, when one reel is full, an empty reel is "struck in," *i.e.*, connected. The back tender or third hand holds a knife against the paper on the last calender roll; this cuts a narrow strip, which his helper pulls off and winds around a new reel, draws tight, and tucks the free end between the sheet and the reel (keeping his fingers out of the nip), while the knife is carried across the sheet. At once, the paper is winding full width on the reel.

On slow machines, the back tender or third hand stands on the front side of the sheet and his helper stands at the back. One hand grasps the edge of the paper near the calenders and snaps the paper across, or else he cuts it with a stick that is held in the free hand. The two men now pass the paper under the reel, catch it on the other side, draw the slack tight, and then tuck it in. The tension of the reel belt is carefully adjusted at once, so the paper draws tight without wrinkling. The full roll is "struck out" as soon as possible.

When a new roll is built up on a roll that is driven, the tendency is for the surface to travel faster and faster; in the present case, this is an impossible condition of affairs, since the paper speed is constant, and one of two things must happen; the paper must break, or the reel speed must change. The latter may be effected by driving the reel with a belt, the tension of which can be so varied as to allow it to slip more or less. This operation must be performed carefully and frequently; otherwise, if the pull on the paper increases or varies too much, the roll will get soft, or it will pull so tight as to make it slip at the center.

294. Two-Drum Upright Reel.—A two-drum upright reel is shown in Fig. 76. While the paper is being reeled onto one of the drums from the calenders, it is being reeled off the other drum onto the slitters and winder. The reel is driven by a belt on pulley P; and on the same shaft that carries P is keyed the main driving gear F, which is in mesh with the gears G, G. The driven gears ride loose on their shafts until the clutches C, C are thrown in by the operator at the front side of the machine, by means of the clutch levers L, L. The reel drums D, D can

be lifted out of their bearings, when it is desired to use a reeling-off stand or to repair the drums.   The front bearings B, B, which carry the driving shaft, are adjustable by means of the hand wheels H, H, to correct for any inaccuracy in the way the paper reels; that is, if the paper tend to travel to one end of the drum, or if it tend to wrinkle, this can be corrected usually by moving the front bearing forward or back.   If the paper is pulling too tight, the tension on the slip belt is lessened a little.
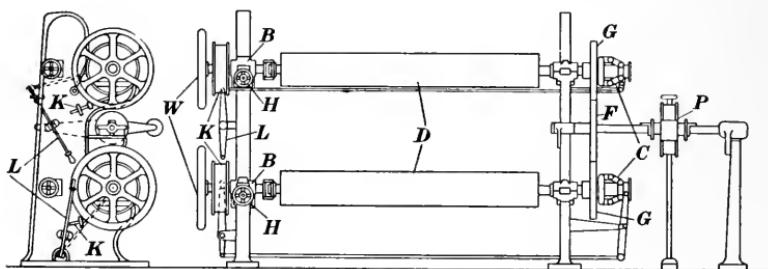
Fig. 76.

295. If a spiral wrinkle persist in forming, the reel journals may be a little out of line; in which case, move the bearing toward the head of the wrinkle, slightly toward the calenders.   A smooth piece of plank, held against the wrinkle, will sometimes eliminate it.

296. Improperly Wound Rolls.—When a roll is soft at the center, it is likely to slide on the reel; this is often due to the outside being wound too tight.   Old timers will sometimes correct this by nailing a piece of board on the reel; but the safest way is to start a new reel, and get it sufficiently tight at the start.   A slipped roll is a difficult proposition for the winder, and it usually makes poor rolls, unless re-wound very carefully.

297. Controlling Paper Tension.—When the paper is being unreeled, the operator can control its tension by means of the brakes K on the pulleys at the front end of the drum shafts, Fig. 76.   The brakes are straps that pass nearly around the pulleys, and they can be so tightened or loosened by means of hand wheels that the work done by the winder is made heavy or light, thus controlling the tension of the paper to the winder and the tightness of the roll.   The tension of the paper from the calenders, as it is reeled onto the drums, is also controlled by the brakes, as well as by the tension of the driving belt on pulley P.

298. Three-Drum Reels.—A three-drum upright reel is
shown in Fig. 77.   Since like parts are here lettered the same as
with the two-reel drum of Fig. 76, the explanation of the latter as
previously given will suffice also for this case.   The only essential
difference between the two is in the gearing, an idler I being
used to gear together the two top-drum shafts; this is used in
order to keep the three drums revolving in the same direction
when the clutches are in.   In the case of both the two-drum and
three-drum reels, the large hand wheels W, shown on the front
side of the machine on each drum shaft, are for the purpose of
starting the paper on the drum, by wrapping by hand a few
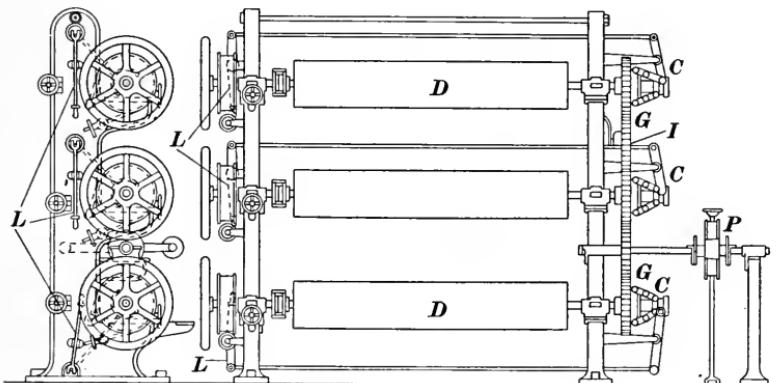
Fig. 77.

turns of paper before putting in the clutch; also to give the paper
a start in threading the winder.   The principal advantage in 3
drums is in reducing the chances for having no empty reel when a
new roll must be started, should there be trouble with a stripped
roll or the winder.

In Fig. 78 is shown a design of a three-drum revolving reel
that is similar in details to the four-drum reel shown in Fig. 74.
In so far as is possible, corresponding parts are lettered the
same as in Figs. 76 and 77, which show upright reels, and this
design may be compared with those.   The levers L are for the
purpose of throwing out the clutches C on the drum shafts, so
that the gears F that mesh with the large driving gear G will
cease to turn the drums when they are not winding paper.
Gears F are loose on the drum shaft, but the clutch is keyed to it.
The large driving gear G is itself driven by the small gear
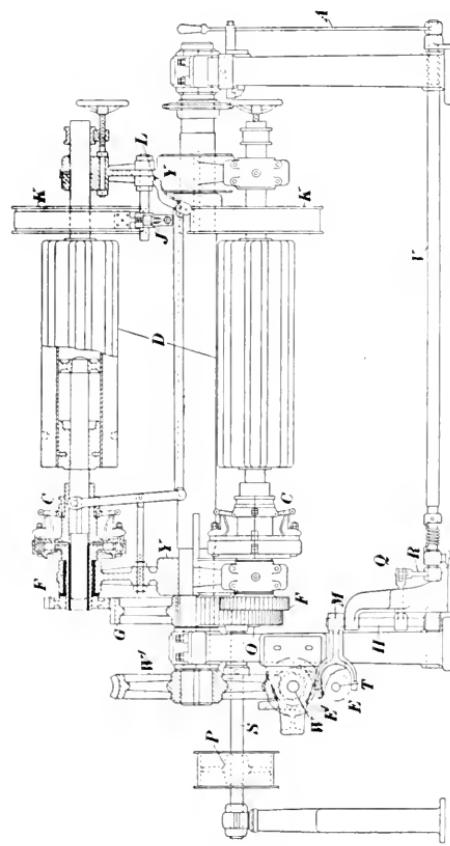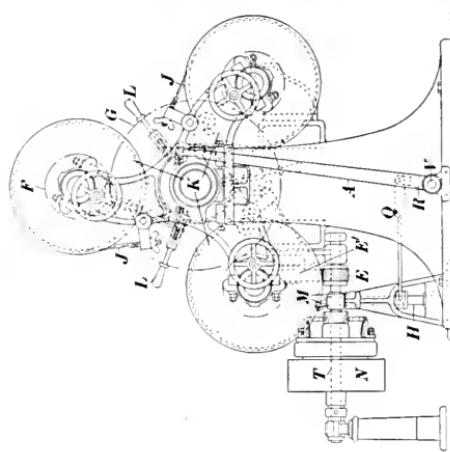
Fig. 78.

O, which is on the driving shaft S; the latter carries a pulley P, which is driven by a slip belt. The tension of the paper is controlled in the same way as in the case of an upright reel, by properly proportioning the tightness of the slip belt and the brakes J on the brake wheels K. The slip belt can be tightened to pull the load easily; then the brake is so adjusted that the belt must exert a somewhat greater pull on the load, so the pull on the paper will not be too hard. On this reel, as on any other, if no unreeling stand is used, the bearings carrying the rolls of paper on the reel can be used for unreeling, so long as the clutch C is not in, and the drum shaft turns idly in gear F.

299. Revolving the Reel Drums.—A revolving reel, whether two-drum, three-drum, four-drum, or six-drum, or any number of drums, must so revolve that every drum can be placed in the most convenient position for reeling or unreeling the paper. For reeling paper, the drum must be near the calender and, for unreeling or changing drums, near the winder.

The method of revolving the three-drum reel shown in Fig. 78 is evident, and all revolving reels are caused to turn in practically the same manner. When a roll of paper is to be reeled up or reeled off, as the case may be, and it is time to move the drums around and bring the next drum in position to reel or unreel paper, the big lever A (see end view) is thrown over; this turns shaft V, and lever R (which is keyed to shaft V) pulls on the end of link Q. The other end of link Q is pinned to an arm on the upright shaft H; and, when Q moves, shaft H is caused to turn in its bearings. Clutch lever M is also keyed to shaft H; thus when H is turned, the clutch M is thrown into clutch pulley N, which is driven by a belt and is loose on shaft T (see end view), to which is keyed the small gear E. Gear E meshes with gear E', which is on a short shaft that carries the worm W, which meshes with the worm wheel W'. The worm wheel W' is keyed to the large central shaft that carries the large revolving spiders Y, Y, which hold the bearings of the drum shafts. Since clutch pulley N is always turning, it follows that when clutch M is thrown in by lever A, shaft T is forced to turn also; this causes gears E and E' and worm W to turn, and it imparts a slow rotative movement to worm wheel W', which causes the three drums to rotate slowly until an empty drum is in the receiving position. Lever A is then thrown back to its former

position, clutch M is thereby thrown out, and the drums stop
their rotative movement.

The type of gearing employed in revolving reels may vary,
but the general principles of design and operation are as just
described.

300. The Slip-Belt Drive.—A type of drive, called a **slip-belt
drive,** is shown in Fig. 79; it illustrates the principle of the drive
that is very generally used on reels and winders.   It is necessary
to describe the reel drive here, so the effect of the drive on the
operation of the reel may be understood.   With this drive,
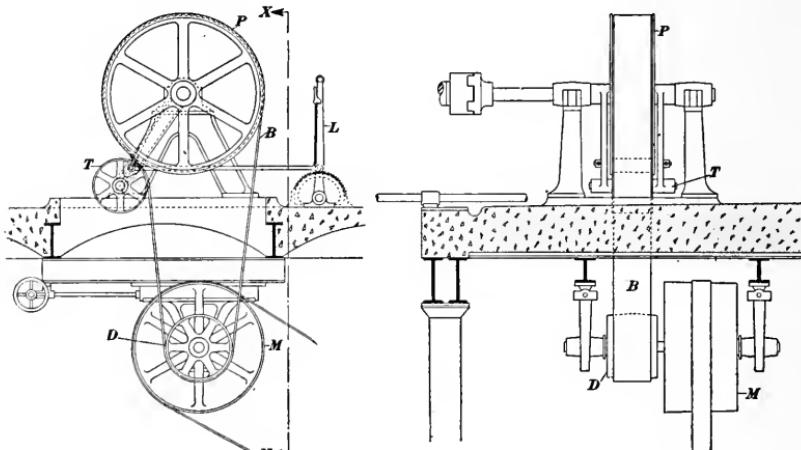
Fig. 79.

the tension of the driving belt B and, what is more important, the
amount of lap around the driven pulley P may be varied by
means of a tightener.   When the tightener T is out altogether,
the belt hangs idly on the top, or driven, pulley P, and the
bottom loop does not touch the driving pulley D, which therefore
turns idly.   Pulley M is keyed to the same shaft as pulley D,
and is driven from the variable-speed shaft or by a motor.   As
the tightener is pulled in by the action of the lever L, the lever
being held in position at any point that gives the required belt
tension by means of the quadrant and pinion shown, the tension
of the belt can be varied from nothing (in the idle position) to
the maximum tension that the operator can give it, up to the
limit of his strength.   When the belt is comparatively loose, it
slips on the driven pulley; in such case, the speed of the reel
drums D, Fig. 76, is slow, the tension of the paper is slight, and

the tightness of the brakes K is small.   By tightening the driving belt, the machine tender can increase the pull by the drums on the paper from the calenders; but should the tension get too high, he can correct this by tightening the brake straps K. This should be avoided, however, as it is a waste of power.

301. Unreeling, or Reeling-Off, Stands.—An **unreeling stand,** also called a **reeling-off stand,** is shown in Fig. 80; an unreeling stand is always used with the friction type of reel.   The reel drum, with its roll of paper R on it, is taken off the reel by use of a compressed-air or electric hoist, and it is placed in the bearings of the unreeling stand.   An unreeling stand is never driven, the paper being pulled off by the winder; consequently, the roll
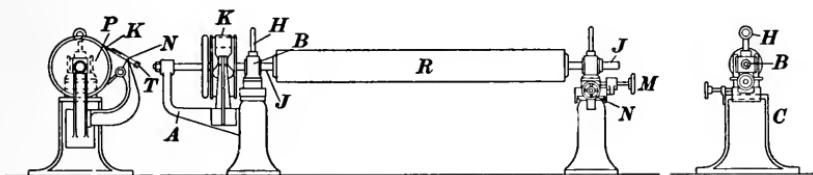
Fig. 80.

on the winder grows larger, the roll on the unreeling stand grows smaller, and the tension of the paper between the two varies greatly, being heavy at first and, finally, very light.   The brake K is used to control the paper tension by means of the thumb nut T, whenever the winder man wishes to alter it; by keeping the tension fairly uniform, the re-wound roll is kept hard all the way through.   The position of the reel drum is so adjusted by the hand wheels M and N that the paper will run true to the winder.   The eyebolts H, which hook to lifting chains on the hoist, are tapped into square blocks B that fit into the unreeling-stand brackets C; these blocks have bushed bearings, and slip over the drum journals J, or the bearings may be split.

302. The Brake Bands.—The brake bands on unreeling stands and reels are subjected to very severe service when they are controlling the tension of the paper to a high-speed winder, say when winding the paper at a speed of 2000 feet per minute, more or less, and the high speed of the pulley within the stationary brake band will soon burn out a leather strap.   These pulleys should be very wide and large in diameter, so as to have ample brake surface.   A pulley of large diameter will have a high

peripheral speed when revolving swiftly, but it takes less force to slow it or stop it. Consequently, if trouble be experienced with brake bands, install a wide-faced pulley of large diameter; then the resulting large surface area will carry away the heat that is generated. With such a pulley, a small pressure per unit of area of brake will control the operation of unreeling. If the brake pulley is large enough, leather may be used for the brake band; but an asbestos brake band might be better.

SLITTERS AND WINDERS

303. Description of Slitter.—Slitters are revolving disks that cut the paper into *strips* as it passes on its way to the winder. A
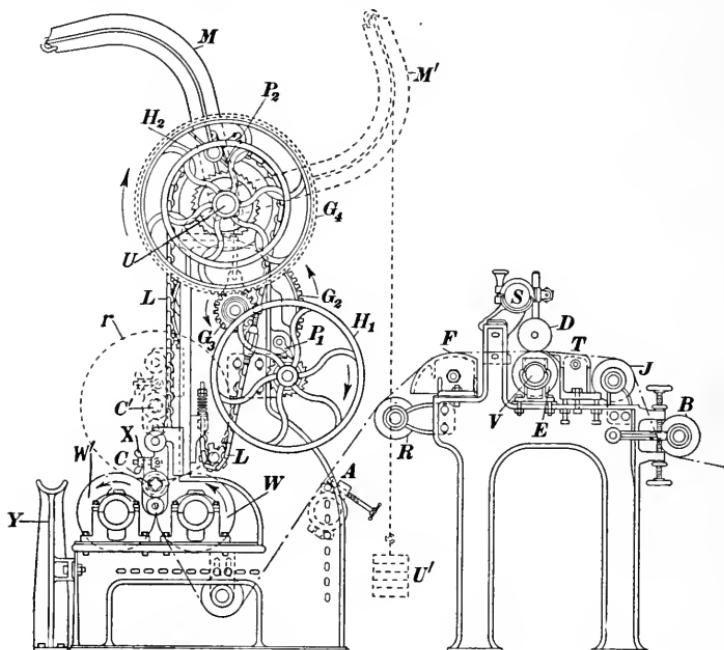
Fig. 81.

slitting machine and a winder are shown in Fig. 81. The paper passes from the reel drum and under the adjustable roll B, which is often supported in spring bearings, in a manner similar to the spring roll between the dryers and calenders. From under roll B, the paper passes over roll J and slitter board T, being thus kept lying smooth and even as it enters between the slitter disks

D and *E*.   After being slit into strips of the widths required, the strips of paper are carefully placed over the curved plate (or roll) *F*, from which the paper goes to the winder.   When a roll is used instead of the plate *F*, it may revolve or it may be stationary, according to the design.   The roll *B* is so adjusted as to obtain an even tension the full width of the sheet, and to prevent wrinkles.

304. The Slitter Disks.—Two views of the slitter disks *D* and *E* are shown in Fig. 82.   The horizontal distance between the adjacent slitter disks is obtained roughly by turning the hand wheel *H* (or a set screw), so that clamp *C* is securely fastened to the cross shaft *Z* that extends across the machine and holds all the slitter clamps.   The vertical position of each upper slitter disk is determined by means of the hand wheel *W* (or a set screw) and clamp *K*.   The position of clamp *H* is such that when lever *L* is in the position shown, disk *D* is pressed against the revolving lower slitter disk by spring *S*.   When the top of lever *L* is thrown over to the left nearly 90° from the position shown, the face *A* of the bell-crank lever is forced against the annular flange *B*.   This pulls the slitter disk *D* away from the lower disk, and compresses spring *S*.   When lever *L* is returned to its original position, spring *S* pushes disk *D* back to the position shown in Fig. 82. The lower disk *E* is made fast to the slitter shaft *V*, Fig. 81, at the proper point for slitting the paper.

The lower slitter disks are rings of cast iron or steel, turned on the outside and faced on the end touched by the upper disk, thus giving a sharp edge for the upper disk to work against.   The lower disks are clamped on the slitter shaft, or else they are fastened on it by headless set screws *N*, Fig. 82; other kinds of screws are not safe.   The slitter shaft *V*, Fig. 81, is so driven that it revolves just fast enough to insure the proper speed to the edges of the slitter disks.   When the upper slitters are brought into contact with the lower ones, the springs *S* exert sufficient pressure to cause the upper slitters to revolve at the same speed as the lower slitters.   When the slitters are not in contact, the paper passes over the lower slitters and under the upper slitters without being cut or injured.   On high-speed machines, it is better to have large lower slitter disks, say 8 inches or 10 inches in diameter. The difficulty with small slitter disks is that, at high speeds, they soon get out of dynamic balance and, therefore, cut irregularly; they are not so easily corrected for poor dynamic balance as the large slitters.

Slitter disks should be kept sharp, and their edges should travel at least 10% faster than the paper; if their speed is slower than this, or is about the same as that of the paper, they will not cut
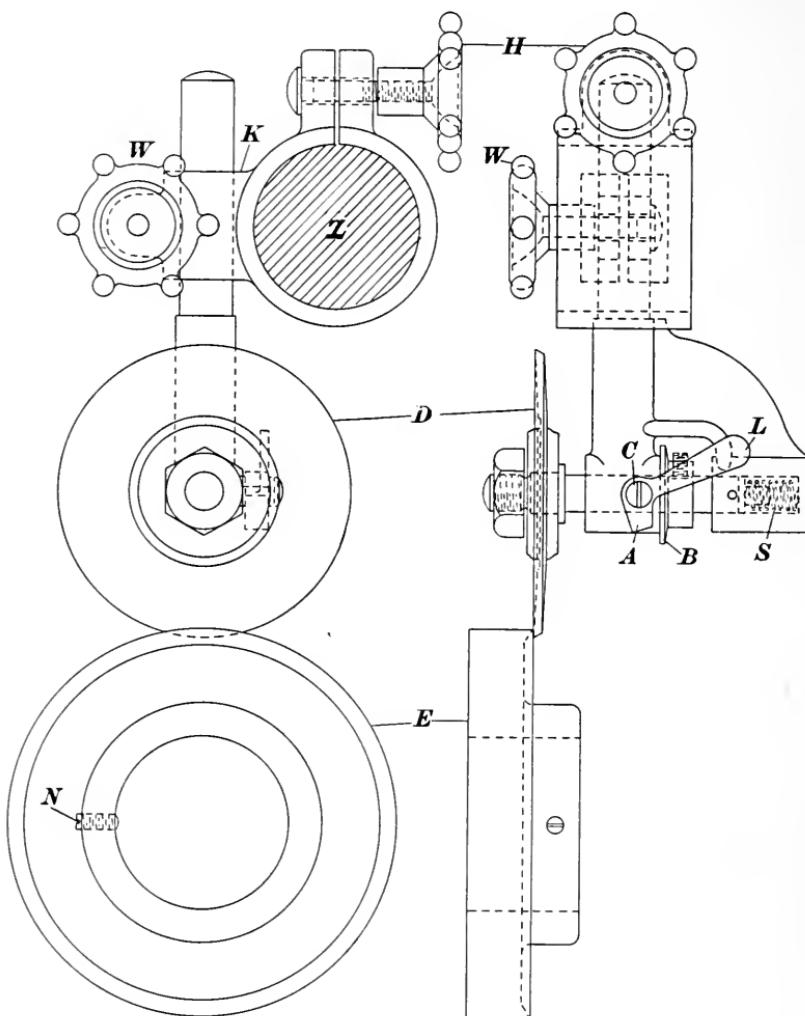
Fig. 82.

clean. The lower slitter disks should be so placed that they project above the slitter board T, Fig. 81, not more than $\frac{1}{16}$ inch.

The shavings usually fall clear of the slitter, and can pass through pipes in the floor to a broke beater below, or they may be carried by compressed air to the tending side and put in a car.

A narrow shaving may wind up on the slitter shaft; it is dangerous
to cut this off without stopping the winder.

305. The Score Cutter.—The slitter is not always in the posi-
tion shown in Fig. 81, nor is it always of the type shown in Fig.
82. A type that differs very markedly from that just described
is shown in Fig. 83. Here A is the roll of paper to be unreeled and
re-wound; P is the re-wound roll, which rests on the winder
rolls W_1 and W; G is a guide roll; and S is the cutter. Winder
roll W_1 has its surface hardened. Cutter S has a V-shaped edge,
and is held against the hardened winder roll W_1 by strong springs;
it cuts the paper by *scoring* it, instead of by shearing it, as in the
case of the slitter last described. The paper passes from roll A
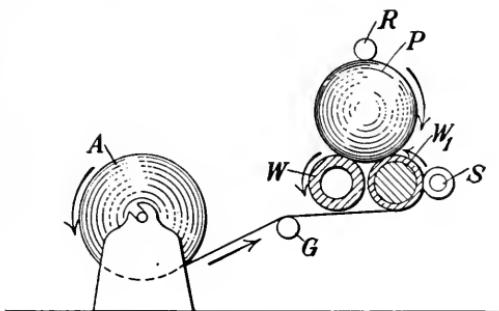
<center>FIG. 83.</center>

over the guide roll G, between the score cutter S and the winder
roll W_1, and then onto the paper roll P, where it is wound up.
The small roll R is for the purpose of straightening and tightening
the roll when first started; this roll is not always used. Sometimes
a separate cutter roll, for the score cutter to press against, is
used, as when the winder roll is so large that it would be very
costly to harden it. As before stated, these slitters cut the paper
by scoring it; a clean, straight cut and well-separated rolls are
obtained.

306. Two-Drum Winder.—The slitter, of either type, and
winder are often combined in one machine, the slitters and the
winder drums being supported on the same frame instead of
separately, as was shown in Fig. 81 (for convenience in describ-
ing), which also shows a two-drum winder to the left of the
slitter. As it leaves the slitters, Fig 81, the paper passes over the
spreader bar A, which presents a smooth, rounded surface to

support the paper. The height of the bar can be adjusted to suit the run of the paper, by moving the brackets either up or down, and by adjusting the hand screws at either end. The inclination of the paper to sag or to vibrate vertically can thus be corrected. The bar A is bent, so it will lift the paper at the center slightly and separate the strips, thus keeping the edges from interlocking while winding into rolls.

The operator passes the paper under the winder and up between the winder drums W and W', one or both of which may be driven. The paper is then wrapped around the cores C; these are usually 3-inch pipes (iron or paper), with notched ends, which slip over a core shaft C, and are held in position by collars. Shaft C is carried in the bearings shown, which are attached to the free end of the chain L. By taking off thumb screw X, the bearings open on hinges, which enables the cores to be slipped over the core shaft. Wooden cores have square holes and fit over a square shaft. As the roll gets larger, the core rises, and the final position of the bearing and of the finished roll is indicated by C' and the dotted circle r.

The arrows show the directions in which the winder drums revolve. It is important that the end drum of the paper machine shall revolve outward on top, to guard against the danger of a man's hand being drawn under the paper roll.

307. Starting the Roll.—When starting a roll, many paper makers consider it easier to pass the paper under both winder rolls, bring it up over the second roll, and then under the core; this means that the winder drums must revolve in a direction opposite to that indicated by the arrows in Fig. 81. When this method of winding is used, a fender or safety guard should be placed after the second winder drum W', so as to guard a man, should he fall in such a manner that his hands might get caught in the nip.

308. Driving the Winder.—The winder is usually driven independently of the paper-machine drive, in order that the starting and stopping of the winder may not cause variations in the speed of the machine and in the weight of the paper; when uniform thickness of paper is essential, this is important.

As the paper roll winds up, it increases in diameter. But since the paper here winds because of its contact with the surface of the winder drums, the paper rolls are kept tight. The paper also

winds at a constant speed; for whch reason, this type of winder drum is called a **constant-speed winder.**

309. Maintaining Constant Pressure on Drums.—As the paper roll r increases in size (see Fig. 81), the weight on the drums also increases; for this reason, some makers have devised means of relieving somewhat the additional pressure on the drums. In connection with the winder shown in Fig. 81, a cord or chain suspends weights U' from arms M attached to the shaft U, which carries the sprocket wheels for chains L. As the roll builds up, the bearings, together with the core shaft C, rise and pull on the tail end of chains L; this turns the upper sprocket wheel, and causes arm M to move to the right. Weight U' also moves to the right, and as the roll gets larger, the pull exerted by U' gets stronger, until the maximum effect is reached when arm M is in the dotted position M' and the roll is in the position r. A grooved wheel and cable may be used in place of arms similar to M.

310. In another type of winder, compensation for the weight of the roll is secured by a set of weights on straight arms (like spokes of a wheel) that stand out from the shaft U. Changes can be made in the angular setting of the arms, the sizes of the weights, and their distance from the shaft. Usually, one weight is set to put a little extra weight on the core shaft when a new roll is started, and the rest of the weights are vertical. As the roll winds up, the main weights revolve, and they gradually pull more and more in lifting the core shaft.

Some makers of winders prefer to let the roll build up naturally, in which case, they provide a large drum to support the full weight, and supply a counterpoise just for cores and shaft.

311. Taking Out Finished Rolls.—When the roll has been wound to the right size, the winder, Fig. 81, is stopped and the paper is broken. The operator turns hand wheel H_1, which turns shaft U by means of the reducing gearing that is made up of gears G_1 (behind the ratchet wheel), G_2, G_3, and G_4; and as shaft U turns, it pulls up on the left-hand part of chain L, lifting the core shaft C and the rolls r clear of the drums W and W', where they are held in that position by the pawls P_1 and P_2. Planks can be slid under the rolls, which are then lowered and the bearings opened, to release the core shaft. The rolls are rolled off to a platform or truck, or lifted off with a compressed-air or electric hoist, the collars are loosened, and the core shaft is pulled out

and placed on the standards Y, new cores being slipped into place. The rolls are then wrapped or are sent to the finishing room. The core shaft is put back into the bearings and lowered into position to start a new roll.

The size of the roll does not necessarily correspond to the size of the reel, but the reels are generally changed so that the rolls may be wound without breaks.

Hand wheel H_2 and pawl P_2 are used for the rapid operation of empty cores or small rolls, as when mending a break.

312. Handling Roll when Paper Breaks.—When a break in the paper occurs, the rolls are lifted, and any spoiled paper is removed, taking care to keep all the rolls on the core shaft of the same diameter. The paper is torn square across, a strip of splicing tissue is laid across the rolls, and the end of the new strips is pulled taut and held firmly over the adhesive. A hot flat iron (266°F.) is passed over the joint, and the loose end of the paper is creased and torn off. The rolls are lowered onto the drums and the winder is started;—slowly at first, until the joint is wound into the roll;—then it is brought up to speed. (See also Art. **324**.) In some mills, the ends are stuck together with flour paste.

313. Angle between Paper Core and Winders.—Referring to the diagram, Fig. 84, R and S represent the winder rolls, and T
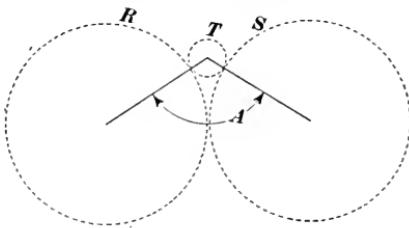
Fig. 84.

the paper roll at the beginning of the winding. Drawing lines from the center of T to the centers of R and S, they form the angle A. As the roll increases in diameter, the center of T rises, and the angle A decreases; in other words the angle A is continually varying with the size of the paper roll. Under these circumstances, it is evident that the larger the angle A the greater is the grip between rolls R and S and roll T. For heavy paper or pulp, the angle A should not be less than 115°; for lighter papers, say up to 30-pound news, angles a few degrees smaller can

be used successfully. It is an advantage to be able to vary the distance between the centers of the winder rolls, so as to have some control of the gripping effect of the revolving drums, as applied to the surface of the paper roll.

314. Grooved Rolls.—It happens, unfortunately, that the perfect conditions required to obtain a "bulls eye," as the machine tender sometimes calls a perfect winder roll, are not easily attained. A winder that works well with one paper and has no adjusting devices, may not work well with another paper. Often a grooved roll, the grooves being parallel to the axis of the roll or else so inclined as to form an angle pointing in the direction the roll is travelling, will enable the paper maker to obtain better winder rolls than with the ordinary ungrooved rolls. The grooved roll tends to offset the bad results due to faulty design in spacing, in diameter, and in crowning of the winder rolls; and when a winder is to be designed for universal service, a grooved roll is an advantage. The grooves further assist in separating the rolls and in preventing interwinding. It may here be mentioned that winder rolls should be crowned just as carefully as lower press rolls. A clever arrangement is used in a Canadian mill to get hard rolls of paper. Both winder rolls are driven by separate belts; when a new paper roll is started, roll W', Fig. 81, is driven slightly faster than roll W, so as to obtain enough friction on the paper to get a tight center. As the roll builds up, its weight increases the friction, and the paper is kept tight on the roll; the belt driving W' is automatically slipped along a cone pulley, gradually decreasing the speed of W' until it has the same speed as roll W.

315. Other Types of Winders.—The details and operation of the winder shown in Fig. 81, are typical of all winders; but the different makes exhibit various characteristics. One make, for instance, has drums of unequal size; thus, the drum corresponding to W in Fig. 81 is 28 inches in diameter, while that corresponding to W' is only 12 inches in diameter. The larger drum carries the greater part of the weight of the roll, and its size gives it greater contact with the paper. The drums are so grooved that the rolls do not run together, and the small drum is protected by a guard, which is automatically kept at a constant distance from the paper. The guard is desirable, because the paper is brought up behind the second roll, not between them, as in Fig. 81, and

the drums therefore turn in a direction opposite to that indicated on Fig. 81. (If the drums in Fig. 81 were to turn in the opposite direction, there would be danger of catching the fingers or the clothing between drum W' and the paper roll r. Rolls turning in this manner would be called "in running" rolls.) Instead of the chain lift on the core-shaft bearings, the winder-shaft bearings are attached to the lower end of racks, which mesh with pinions that are operated simultaneously by worm gears. The racks run through rigid guides, to take up the end thrust on the winder shaft. On these winders, ball bearings are extensively used.

316. Four-Roll Winder.—An important development of this type of winder is the use of 4 drums and several core shafts. This prevents entirely the interwinding of rolls, since no two rolls are adjacent. The shafts are short, and they are confined to the outside ends, to take care of the side thrust. A great advantage of this design is that, if there be a streak or defects in one part of the sheet, the defective paper may be cut off from *one* roll, something that is impossible with a two-drum winder, since the paper on one roll would not be pressed against the winder, in that case, and a poor roll would result.

317. Compensating Winder.—On paper machines, the compensating winder has largely been supplanted by the constant-speed type. The former (older) type is still common on board machines, and will be fully described in that connection. The main principle that governs its design is to have a set of core shafts, usually 2 or 4, driven through a set of spur and differential gearing. The difficulty attending its operation is that the core shafts run at constant speed; thus, as the rolls grow larger, the speed of the paper increases until it becomes very great, which often causes trouble in winding. It is also difficult to have the rolls uniformly solid.

318. The Cutter.—It has been stated that on high-grade, tub-sized, and air-dried writing papers, it is customary to cut the paper into sheets just after passing through the size tub. With papers that are dried and, as usual, calendered on the paper machine, the cutting may also be done in the machine room, as the paper comes from the slitters. This practice eliminates the winder and the troubles incident to its operation. Where the paper is to be sized in the full width of the sheet and

cut in the finishing room, the paper is dried by an auxiliary nest of 5 or 6 drying cylinders, or by one of the systems of air-drying described in *Tub Sizing and Finishing Operations*, Vol. V.

The advantageous use of a cutter here depends on the weight of the paper and the length of the sheet to be cut. The cutter knife can make only a certain number of revolutions per minute effectively and efficiently, and it can operate faster on relatively thick than on thin papers, since the sheets are then delivered and piled better, as they are cut. The longer the sheet the faster is the paper taken from the reel, and, hence, the greater is the possible speed of the machine. If the cutter is making 70 clips per minute on 24″ × 36″ sheets, the long side being with the grain, the possible machine speed is $\dfrac{70 \times 36}{12} = 210$ ft. per min., which would be a fair speed on heavy, high-grade book paper. The cutter, which is combined with an automatic piling device, or layboy, is fully described in Vol. V, in the Section on *Tub Sizing and Finishing Operations*.

WINDING TROUBLES

319. Variable Tension.—At the start of the winding, the tension, or pull, on the paper is light, and it is adjusted by the brake band on the reel or unwinding stand. As the winding speed increases, the tension increases gradually, until the paper is winding tight and hard. It is very important to get a good hard center; otherwise, when the outside gets hard, as the roll builds up, there is almost a certainty of trouble with slipped rolls. With compensating winders, the speed becomes terrific as the end of the roll approaches; and after the half-way point, say about two-thirds of the finished diameter, it is necessary to gradually reduce the tension of the brake bands, and, in some cases, even to let the reel run loose.

320. Wrinkles.—Wrinkles may originate at the reels or at the winder. It is easier to prevent a wrinkle than to remove it; but it is sometimes impossible to do either, if the fault is with the paper before it goes to the reel. A good roll at the reel will almost invariably run well on the winder. The only remedy for a wrinkle is to adjust roll *B*, Fig. 81, in such a manner as to get the proper tension the full width of the sheet. If the paper be slack on one edge, the corresponding end of roll *B* is lowered.

If a wrinkle start, the end of *B* toward the head of the wrinkle is raised. In some cases, instead of moving roll *B*, one of the bearings on the reel, or unwinding stand, is movable, and this may be adjusted.

321. Curled Edges.—With compensating winders, one edge of the roll may display a tendency to curl and to run higher than the body of the roll; in time, such an edge will crack. The trouble is that the slitters are dull, or they run too slowly, or the upper slitter is so set that it overlaps too much on the lower slitter. The temporary remedy is to lean a board or plank against the high edge, thus retarding the increase in diameter of the roll at this point. Curled edges are sometimes caused by defective conditions at the dryers.

322. Slipped Rolls.—The slipped roll is the dread of the winder man. When a roll is wound loose at the center, and is thus harder on the outside, it is likely to slip sidewise; or a portion of the roll may slide out, especially if one side of the roll be softer than the other by reason of uneven thickness of the paper. The usual remedy is to attach a clamp on the core shaft, to hold the center of the roll in place. It is best to bolt the clamps fast when the machine is stopped; but the two parts are sometimes fastened together loosely around the shaft, slipped into position, and held there by winding a cord around the shaft and against the roll clamp. This is dangerous, even when the winder is running slowly, and it should never be attempted when the winder is running at high speed. This trouble is more often experienced with compensating winders.

323. Roll Slips on Reel.—Trouble is also caused by the slipping of the roll on the reel. When this occurs, a stick should be nailed on the reel, to check it, if it has not already been done. This may make a dent in the edge, which may cause the paper to break on the winder. The chief difficulty is this: the slitters have been set to cut a shaving $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches wide from either edge of the paper, $\frac{1}{2}$ inch being about the smallest that can be handled; hence, if a roll slips on the reel, it may cause a very wide shaving on one side and a very narrow shaving, or none at all, on the other side, even leaving a rough edge on the sheet on that side. Fortunately, the reeling-stand, or unwinding-stand, bearings are adjustable endwise, to take care of just such cases. If for any reason, the movement of the bearings will not make up for the

slip, it may be possible to slide the paper on the drum by bumping the end of the drum shaft with a piece of shafting or the like, much as one would drive the head on a hammer by hitting the other end of the handle. If these remedies do not work, let the paper run through, and then cut the poor paper from the outside of the roll or sort it out in the finishing room.

The matter of shavings must again be considered when, perchance, the shaving winds up on the roll; this is sure to annoy the printer or the supercalender man. If the shaving runs over, adjust the guard on the edge of the sheet, and look to the width of the paper. Sometimes the stock gets shorter or slower, and shrinks more on passing through the machine. In this case, pull out the deckles or make the stock more free. The lighter the sheet the wider must be the shaving.

324. Breaks in the Paper.—Another source of worry to those who receive the rolls is the matter of breaks. If the paper is to be supercalendered or cut to sheet length, the breaks are not usually spliced; but if it go to the printer, the two ends are joined with splicing tissue, or by pasting, as was briefly described in Art. **312.** The entire process is fully discussed by E. P. Cameron in the *Pulp and Paper Magazine of Canada* for Oct. 2, 1919. As soon as a break is repaired, it should be "flagged," by putting a piece of stiff colored paper into the roll, allowing it to stick out at the side; this is a warning to the press man.

325. Important.—Perhaps the most important point in running a winder is to see that the slitters are set right. The best way of accomplishing this is for two or more members of the crew to read the machine order, and for each to measure the rolls accurately.

NOTE.—The description of the paper machine is continued in Vol. V, Section 1. Part 1 of this section will treat of *cylinders* and *special machines*, etc. Part 2 will treat of the *Paper Machine drives,* including the usual mechanical driving arrangements and the latest developments of the electric drive.

PAPER-MAKING MACHINES

(PART 4)

EXAMINATION QUESTIONS

(1) (*a*) What is the purpose of the spring roll at the calender end of the dryer part?   (*b*) Can you devise another arrangement to accomplish the same purpose?

(2) (*a*) Why is the calender dangerous?   (*b*) How may accidents be avoided?

(3) Explain the purpose and action of the calender.

(4) Describe a calender stack, and state the course of the paper through it.

(5) (*a*) What is the effect, as regards calendering, of too much, too little, or just enough moisture in the paper?   (*b*) How can the moisture content be controlled?

(6) Mention some calender troubles, their causes, and their remedies.

(7) (*a*) Why is the bottom calender roll crowned?   (*b*) Give your own ideas as to the reasons for the various sizes and crowning of the different rolls in the calender stack.

(8) Explain what effects are produced on the paper by improper crowning.

(9) (*a*) Why is a reel necessary?   (*b*) What are the principal types?

(10) Describe what you consider to be the best type of reel, and explain why you consider it superior to any of the other types illustrated.

(11) How is the tension of the paper controlled during winding?

(12) Explain the principle governing the operation of each of two types of slitters.

(13) Describe the two-drum winder.

(14) How does the four-drum winder differ from the two-drum type, and why are both better for most purposes than the compensating shaft-driven winder?

(15) (*a*) How is the roll started on a two-drum winder? (*b*) What is meant by in-running rolls?

(16) (*a*) What causes a slipped roll? How is it checked (*b*) on the reel? (*c*) on the winder?

(17) What is done in case of a break in the paper being wound?

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